SECOND-PROGRESS REPORT AND THIRD-YEAR BUDGET

INTERNATIONAL BIOLOGICAL PROGRAM (IBP)

ISLAND ECOSYSTEMS STABILITY AND EVOLUTION SUBPROGRAM

NSF Grant GB-23230

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Preface

The Island Ecosystems Integrated Research Program (IRP) of the US Contribution to the International Biological Program (IBP) has been active for 18 months. The program is centered in Hawaii.

The original name of the program, HAWAII TERRESTRIAL BIOLOGY SUBPROGRAM was changed early last year to ISLAND ECOSYSTEMS STABILITY AND EVOLUTION SUBPROGRAM. The change of name was made to indicate more clearly the main objectives of the program, which are to study the ecology and evolution of island biota and communities and to interprete these in the context of island ecosystems stability. Moreover, our program is concerned with developing principles that are not only applicable to the Hawaiian Islands, but to island ecosystems in general.

The program emphasis is on basic research with an equally strong orientation to the solution of regional problems and the practical issues of today, wherever they are concerned with the interaction of man and the biological resources of islands.

Endorsements: The budget request for the Third Year (September 1, 1972 to August 31, 1973) as detailed at the end of this report, amounts to $657,734. We request that this sum be made available in two separate institutional grants as before, one to the University of Hawaii, the other to the B. P. Bishop Museum.

Respectfully submitted,

University of Hawaii	B. P. Bishop Museum
Dieter Mueller-Dombois Director	J. Linsley Gressitt Co-Director
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AIMS OF ISLAND ECOSYSTEMS PROGRAM

The scientific objectives of the program remain unmodified from our funded February 1971 proposal, and the framework within which they are pursued is beginning to show well defined aims. These may be stated as follows:

- to integrate the study of ecology and evolution
- to help solve regional (island) problems
- to include man in the island environment
- to broaden our base through comparisons with other island ecosystems and through international coordination
- to develop research integration as a continuing modus operandi for island ecosystems research

Integration of ecology and evolution

Our program title is ISLAND ECOSYSTEMS STABILITY AND EVOLUTION. There are two basic parts to the program:

A. Evolution of species
B. Ecology of species and communities

From the beginning, we have wrestled with the problem of how to combine the two parts so that they would serve as a meaningful interpretation of island ecosystems. The solution we offered was to study the evolution and ecology of species in the context of the community and then in the context of the ecosystem.

Therefore, we intend to bring our studies in population genetics and autecology (life history) together in accordance with the fact that in nature populations of biota occur in communities. For this reason, we developed the approach:

1. species identification
2. quantitative enumeration
3. sociological interaction
4. physiological ecology
5. synthesis models

This approach was developed with respect to specified island communities and ecosystems, known as IBP transects and study sites. The approach is considered sequential, but progress is not necessarily tied to this order. Many of us are still in stage 1 and 2, others have progressed to stage 3, or are progressing from 1 to 3 to 2. Stage 4 may be carried out by the same individuals working on 1 through 3, or it may be handled by different investigators specializing in physiological ecology. Stage 5 is emerging around various areas of emphasis that are discussed under INTEGRATION OF RESEARCH TASKS.

A major condition for the workability of our approach is coordination of sampling and research in the same ecosystems. Therefore, SITE COORDINATION is an essential part of our program, which is discussed in a separate section in detail.

Our more immediate evolutionary objectives are to learn about mechanisms and rates of speciation; these are studied on an intrapopulation level. This means that some of the evolutionary studies will have to be pursued in areas outside the specified IBP sites. Evolution of species and their autecology can be studied to some extent without a detailed knowledge of the ecosystems. However, the study of species evolution and autecology of species and communities is not our ultimate aim. Our scientific aim is to combine these research orientations, to be able to interprete adequately the evolution of ecosystems, and to predict the degree of stability of these systems in island environments.

1. Species identification

We considered stock taking of our biological resources as the necessary first step. In particular, this involved the preparation of checklists for specified IBP sites. For some of us, this phase is more complicated and absorbing than for others. Therefore, progress in this first stage is necessarily at different levels.

2. Quantitative enumeration

Most of our work is currently done in this area, and much more needs to be done. In studies with short-lived organisms (insects, fungi, algae), quantitative sampling must be periodically repeated and much of our third year budget will be expended in more assistance for routine sampling. The aim of this second step of our studies is to establish the basic population and community patterns.

3. Sociological interaction

The interpopulation structure and dependencies form the central core of our ecological objectives. This is the area in which we hope to construct simulation models for predictive purposes.

4. Physiological ecology

Metabolic processes, tolerances to environmental stress, and organism function under field conditions are information elements essential to explain ecosystem stability. To this end, we intend to go further into process studies along the lines established by the interbiome committees. Some of us are already working on problems in physiological ecology.

5. Synthesis models

All subprojects can be fitted into an overall island ecosystem model.

However, this model is as yet merely an idea of how the various subprojects are organized in relation to the essential ecosystem components. On a more practical working level, a number of research emphases are emerging from closer integration of research tasks and increased information exchange. Such integrated tasks include the study of seasonal phenomena in relation to phenology, insect-consumer processes and others that will provide the data pools from which sub-systems models can be built. It is anticipated that the synthesis of subsystems will eventually lead to workable syntheses at higher levels that can be assembled for specific predictive purposes.

Regional problems

Each environmental program of the US/IBP has its particular set of scientific and practical problems.

Scientific problems

In the Biome Programs the scientific problems of ecosystem function are focused on a specific ecosystem structure in each case. The ecosystem structure is given by the principal life form (herbaceous, evergreen trees, deciduous trees,etc.) and its arrangement in space (closed herbaceous = grassland biome; sparse mixed herbaceous, succulent and woody = desert biome, etc.). Similar ecosystem structures are encountered among the Island ecosystems, except that each one -- alpine tundra, rain forest, seasonal forest, grassland and desert -- occurs on a much more restricted geographic scale. To obtain a reasonable degree of island ecosystems representation of our research, we are concerned with a cross-section through all of the island-parallels of the continental biomes.

Because of their different origin in the island environment, we can also expect considerable functional departures of the island parallels from the continental biomes. Evolution of the same basic ecosystem structure in biogeographically unrelated areas (North and South America) is the basic research inquiry of the Desert and Mediterranean Scrub Subprograms. Essentially, we are asking the same questions when contrasting island and continental ecosystems.

Regionally unique and related specifically to island environments

- is a certain simplification among taxonomic entities because of limitations in arrival forms.

- This has lead to generally low species diversity within island communities whereas, in contrast, species diversity between communities and island localities is rather high, making for increased uniqueness of any individual island ecosystem.

- At the same time, structural complexity similar to continental ecosystems has evolved in time from these limited arrival forms to the extent of at least development of parallel biomes, but some of their functional departures are obvious.

- Definite limitations in size of habitats have imposed limitations in number of individuals in island populations, particularly among the larger life forms.

- Both, limited number of taxonomic arrival forms and limited number of individuals per population, have resulted in evolution of ecosystems that are specifically adapted to island conditions. But these appear to have lower homeostatic capacities to technologically induced changes than continental ecosystems.

This leads to certain practical regional problems.

Practical regional problems

Because of the size limitations of their populations and habitats, island biota are more susceptible to extinction than continental biota. Another important reason is that island biota evolved in environments where the stresses were different than in continental areas. Certainly, some violent perturbations, which are associated with volcanism, hurricanes, flash floods, land slides, tsunamis, and possibly fire, are part of the stress factors of volcanic islands, but these are locally restricted to specific habitats so that island populations could recover from refuge areas. Moreover, the periodicity of these environmental disturbances has probably been low.

New stresses have been introduced that are associated with the activity and necessities of man. Technological impacts are of a different nature and dimension than those now noticeable in many continental regions. For example, as yet, we do not have to be concerned about the absorptive capacity of forests to airborne and precipitated industrial pollutants. Instead, most of our impact problems are related to the small size of island habitats, the limited replication of island communities, and the vulnerability of island biota to competitive stresses of certain introduced biota against which no natural controls have evolved in the island ecosystems. Therefore, the absorptive capacity of island ecosystems to non-evolutionary stresses is more limited than in continental ecosystems. Their delicate balance needs particularly careful study before managerial practices are introduced that are otherwise quite accepted for continental ecosystems.

Current issues related to man's impact

Man is part of the ecosystem. This includes island ecosystems from a size limit and quantity of fresh water supply. As long as man operated within such island ecosystems without his extended arm of technology, he more or less preserved the instinct to adjust his needs to the limitations imposed by the island ecosystem. This has changed with the introduction of western technology. The natural limitations of island ecosystems were extended by technology, and the current issues relate to the impact of technological man.

The big problem is to understand island evolution and to bring this understanding into the management of island ecosystems. In the State of Hawaii, half of the 4 million acres of land surface is currently still under forest, scrub and other non-agricultural vegetation. Management on this portion of the land should be carefully oriented on basic research so that the remaining island biota and communities are maintained in perpetuity and that also the needs of man, culturally and economically, are satisfied. To this end, our program is designed.

Highest among information needs are the following three, in order of priority:

1. Exact knowledge of the effect of introduced large herbivores on island ecosystems.

2. Knowledge of how to maintain island vegetation cover and for what purposes.

3. Increased knowledge of water yields and water circulation in relation to natural and technologically modified ecosystems.

1. Introduction of large herbivores

Pigs were introduced by the Hawaiians, probably 1,000 years ago, goats and cattle by the white explorers about 200 years ago, sheep, black tail and axis deer more recently. These mammals did not evolve as part of the island ecosystems. Consequently, their impact is most destructive unless very tightly controlled.

So far, there has been very little scientific information on the impacts of large herbivores on Hawaiian ecosystems. We have redirected some of our program efforts, in particular those concerning the native tree species <u>Acacia koa</u> (koa) with respect to its depredation by goats and pigs. During the course of our studies, these animals emerged as probably the major interference factors in the reproduction cycle of koa (see reports B-1a, B-2a, B-4b). The effects on other plants and ecosystems without koa were also investigated (B-1b).

We intend to enlarge this study by a behavioral study of goats that will be concerned with troop-size, migration patterns among ecosystems, sex ratios, reproduction rates, vegetation food preferences, and amounts of plant intake. Such a study will complement our current studies on vegetation response. The behavioral study on goats is to become part of subproject D-2 under the direction of Dr. Tomich and will be carried out by K. D. Abbott, who will join our program as a postdoctoral fellow for FY 73. Similarly, we intend to expand our study on the effect of pigs in the montane rain forests along the lines indicated in report B-2a.

Knowledge on the impact of goats and pigs on Hawaiian ecosystems is of top priority to the U.S. Department of Interior in devising their National Park management in Hawaii. The standing National Park policy is to maintain public parks in their natural state. In island ecosystems, this can only be interpreted as meaning park maintenance in a state which was formed through the stresses of island evolution. This would imply management to exclude the man-introduced, non-evolutionary stresses.

Scientific knowledge of large herbivore impact is also of great importance to the USDA Forest Service and the Hawaii State Department of Lands and Natural Resources whose main resource program No. 3 is "Management of recreational and wildlife habitat resources."

For further information on this problem, see POSITION PAPERS NO. 1 and 2 in this report.

2. Maintenance of island vegetation cover

In its new 1971 Forest Conservation Research Plan for the Seventies, the Hawaii State Department of Lands and Natural Resources, in collaboration with the U.S.D.A. Forest Service, considers aids to decision making crucial. The Plan emphasizes that most problems are multidisciplinary, and that the ecological base needs strengthening. The Hawaii International Biological Program is mentioned as an important new way to bring basic research on island biotic communities to bear on practical problems. Under recommended studies on forest ecology and silviculture, at least 15 topics are directly from our funded IBP proposal and Technical Report #1.

Therefore, the role of the ISLAND ECOSYSTEMS IRP (Integrated Research Program) is emerging as a major advisory body on ecological resource management. There is a clear expression in the Plan for the Seventies that Hawaii land management has to be based more strongly on basic research.

Current U.S. Forest Service research in Hawaii emphasizes the decline of native ohia (Metrosideros collina subsp. polymorpha) and koa forests. Much effort is directed into studying the rate of spread of ohia dieback and a search for its causes. Less research effort is directed to the study of intact native forests, although some recent plans have been made to study the silviculture of Acacia koa and the maintenance of the high altitude mamani (Sophora chrysophylla) forest on Mauna Kea.

Yet the 1971 Forest Planting Plan of the Division of Forestry, State Department of Lands and Natural Resources, does not include these important native tree species. Instead, the plan is to plant nearly 6,100 acres of public lands in a five-year program to an assortment of 17 different exotic tree species for a cost of 1.3 million dollars. Among the trees for planting are 5 species of Australian eucalypts and 3 species of southern pines.

The problem is that silvicultural knowledge exists only for these exotic tree species. Practically nothing is known on the propagation of native forest tree species. There is no seed collecting program, no nursery stock, and areas requiring reforestation cannot be supplied with native tree species in the planting program.

However, there is a strong demand for koa wood, which has hardwood qualities superior even to walnut. A similar demand is developing for Hawaiian tree fern logs that are used as substrates for the local orchid and cut-flower industry.

Ecology of Acacia koa

Koa research was included in our initial program strictly for its scientific value. A study of koa growth rates (see B-4b) and reproduction behavior (see B-4c) is, however, of important practical value for koa silviculture. We intend to continue such work, while the more operational research, such as seed production rates and seed harvesting, raising of nursery stock, planting techniques, spacing trials, thinning studies, and selection of superior trees, would fall more directly into the area of the Hawaii Forestry Program. A close coordination of IBP and Forest Service research activities is expected to evolve, depending on the talents available.

Our koa research for 1971-72 was supported, in part, through a grant from the Bishop Estate, a large land-holding corporation in the Hawaiian Islands. We intend to expand research on this important forest-forming native species by studying its evolutionary behavior in relation to photosynthesis, transpiration, and energy exchange. Details of this study phase on koa are described under subproject B-4d (see item #14 under SUPPLEMENTARY INFORMATION).

Ecology of Hawaiian tree ferns (Cibotium spp.)

There is similar gap of knowledge in tree fern ecology. The Hawaiian rain forests still hold large quantities of tree ferns. This resource is looked upon by tree fern users as a potential supply. However, we have some reasons to believe that the tree ferns are the most important stability factor in the Hawaiian rain forest ecosystems. If they are removed, it seems, the forests are readily invaded by exotic weed plants (for additional information on this viewpoint, see POSITION PAPER NO. 3.

Therefore, we have redirected our fern program (subproject B-5) to a thorough investigation of the ecology of Hawaiian tree ferns. Part of this subprogram will be developed to specifically investigate the competitive capacity of Hawaiian tree ferns (Ph.D. dissertation topic of Richard E. Becker, graduate research assistant on B-5). The other part will be devoted to find out as much as possible about tree fern farming for local needs to prevent further mining of tree fern resources in the future.

Application of koa and tree fern silviculture

There is a place for both koa silviculture and tree fern farming in the Hawaiian Islands, particularly on the island of Hawaii.

Many original koa habitats have been converted to grazing land; others, on a smaller geographic scale, to plantation stands of eucalyptus and other exotic species. Where such converted grazing land is on shallow, rocky soils in high rainfall areas, grassland productivity appears to be marginal and cattle grazing wastefully extensive. We have a productivity study underway on such grassland (by Dr. G. Spatz, not yet among our progress reports) where koa silviculture seems a far better utilization of the land. If scientific information supports the contention that prompted this comparative productivity analysis, land use policies should be corrected. Similarly, after eucalyptus stands are cut, koa silviculture should be attempted on such sites for two reasons: (1) the restoration of forest as a potential habitat for recovery of koa-associated native biota; (2) the much superior quality of koa wood, which competes with walnut and other high-priced, fine hardwoods.

From all of the evidence so far at hand, it does not seem too difficult to gain sufficient knowledge for practicing koa and tree fern silviculture on an operational scale within approximately the next 5-10 years. However, a successful operation has a tendency to expand rapidly. The mainland demand for koa wood may become so high that advance planning for a balanced use of the available island habitats is of extreme importance. The IBP studies on ecosystem stability will be of great importance for resource use planning. (For additional information, see POSITION PAPER NO. 4.)

Water yields from island ecosystems and their water circulation patterns

Forest watershed management ranks highest among Hawaii Forestry objectives. Fresh water supply is certainly one of the most important practical problems, and may determine, among other factors, the sustained carrying capacity of islands for human populations. While certain research efforts have gone into water-yield problems, more knowledge of comparative yields under different vegetation covers and knowledge of water budgets of different ecosystems is of considerable value. We intend to monitor water and radiation budgets in our intensive IBP study sites as a contribution to the information on water cycling in Hawaiian ecosystems (subproject G).

Comparisons with other island ecosystems and international coordination for follow-on programs

Looking ahead as a multidisciplinary research group, we are deeply interested in extending our studies for comparison purposes beyond the Hawaiian ecosystem transects to other island ecosystems.

The University of Hawaii field biologists and researchers of the Bishop Museum already have a long-standing interest, and have established many contacts with research institutions and individual investigators, in other tropical island areas of the Indo-Pacific Region. Another group, with similar interests and with closely established liaison to the ISLAND ECOSYSTEMS IRP, is the Smithsonian Institution.

In the planning stage of the U.S. contributions to IBP, a team within the present ISLAND ECOSYSTEMS IRP and Smithsonian Institution set out to explore a system of validation sites in the tropical region of the Indo-Pacific. The outcome of this site location study was published under the title "Initial Site Studies for the International Program in the Tropical and Far Western Pacific" (Micronesia 5(2): 283-293, 1969, by Doty, Fosberg and Mueller-Dombois).

Contacts were made with several National IBP committees in SE Asia and with International researchers interested in IBP in such island areas as Ceylon, Java, Borneo, the Philippines, the Southern Ryukyus, Micronesia and New Guinea.

The guide lines for this site location study were to determine:

1. The availability of suitable sites for IBP studies.
2. Positive interest on the part of the host country and host agencies in having these sites used as IBP study areas.
3. Assurance of protection of the sites for the purposes of IBP.
4. The availability of aerial photography for the area.
5. The availability of other information such as weather observations, soil studies, and some knowledge of the biota at least through the taxonomic phase.
6. Ready accessibility from outside of the country and from the cooperating institutions or scientific centers within the country.
7. Matters of primary importance such as the waiving of customs and immigration barriers to moving scientific material and personnel in and out of the site or country.
8. The amount of effort that the host country or institutions would commit to the particular programs.
9. Comparability of the sites topographically and climatologically, and with both primitive and secondary (disturbed) areas in a gamut of climates; availability of fresh water and terrestrial habitats at different elevations.

A next step was to begin with assembling detailed information as site preparation for intensive IBP studies to follow. The kinds of information gathered were to be along the lines of our IBP site preparation program in Hawaii, the "Atlas for Biecology Studies in Hawaii Volcanoes National Park" (Hawaii Botanical Science Paper No. 2, 507 pp., 1966). Considerable groundwork was done and progress made particularly in Ceylon, Indonesia and New Guinea.

Ceylon

In Ceylon, a foreign currency (PL-480) program, the Smithsonian-Ceylon Ecology Project (under the direction of Drs. Fosberg, Abeywickrama and Mueller-Dombois), was active for 2½ years (1967-69). Coordinated with this was a Smithsonian-Ceylon Elephant and Primate Research Program (under the direction of Drs. Eisenberg, Crusz and Ripley). This was concerned with behavioral studies of these animals in Ceylon's Wildlife Sanctuaries and National Parks. The Smithsonian Flora of Ceylon Project (under the direction of Dr. F. R. Fosberg) is still active on the revision and updating of the well-known classical tropical work of Trimen, "The Flora of Ceylon." Vegetation maps and other environmental maps were prepared for two National Parks in Ceylon. A number of papers relating to Ceylon's wildlife and vegetation in the lowland and montane environments were published and others are still forthcoming. These are most suitable preparatory studies from which specific hypotheses can be developed for follow-on studies by the ISLAND ECOSYSTEMS IRP. Close ties were established with the Ceylonese IBP, and the stage is now set for further integrated projects involving multidisciplinary research.

Indonesia

In Indonesia at least three suitable study sites were located: (1) an island transect: Mount Gedeh-Pangaranga-Tjibodas, (2) Udjung Kulon and (3) Amboina. A site preparation study was made for Udjung Kulon by Dr. Lee Talbot. The results of Talbot's study were presented in four reports, proposals and recommendations.

Udjung Kulon is still only a partially explored area of approximately 225 square miles; it consists of lowland forests with clearings in several places made to provide grazing grounds for the wild animals; the highest peak is approximately 300 meters; the area is very rich in large animals, including the rare Javan rhinoceros, and many unique plant species. Located at about 6 deg., South Latitude, and 105 deg., 20 min., East Longitude, it is a coral-rich area. The famous volcanic series of islands, popularly known as Krakatau, is but a few miles to the north and possibly could be included, at least as an unprotected site. Udjung Kulon itself is provided with a very favorable management program and positive protection. It is approximately one easy day's travel from the major scientific center at Bogor and about the same accessibility can be had from the port of entry, Djakarta. The National Biological Institute of Indonesia and the Forest Institute would provide all the cooperation possible toward the end that this site be cooperatively used as an IBP study area.

This area has been the object of a great deal of scientific study and is a major objective of the people concerned with conservation. Currently there is a book being written about this area by Dr. A. Hoogerwerf, and a year-long study of the Javan rhinoceros has been undertaken by Dr. Jacques Verschuren, under the sponsorship of IUCN. Dr. Harold Coolidge, President of IUCN, has arranged for construction of a boat for this Park.

However, although we are strongly concerned with the study of still relatively undisturbed island ecosystems, we are equally concerned with the interaction of man in island environments and his resource requirements. A recent Pacific Science Association Symposium in Indonesia was organized by Drs. M. S. Doty and V. J. Krajina in collaboration with Indonesian scientists from LIPI (Indonesian Institute of Sciences) and BIOTROP (Regional Center for Tropical Biology). The symposium was named "Planned Utilization of Lowland Tropical Forests." Several members of the ISLAND ECOSYSTEMS IRP contributed papers or participated. A report on this International Symposium has just been published by UNESCO (December 1971 issue of "Nature and Resources" pp. 18-21, D. Mueller-Dombois).

New Guinea

A third island area in which our program has a particularly great interest is New Guinea. The Bishop Museum already maintains a research station there, known as the WAU ECOLOGY INSTITUTE. An outline of the bioecological characteristics of New Guinea is given in the following account by Drs. P. van Royen and J. L. Gressitt. The opportunities for comparative validation studies are excellent for both, the ISLAND ECOSYSTEMS IRP and the TROPICAL BIOME of the US/IBP.

NEW GUINEA AS LOGICAL AREA FOR COMPARATIVE ECOSYSTEM STUDIES

(P. van Royen and J. L. Gressitt)

New Guinea is the second largest island, with an area of over 0.8 million sq km. Situated between 0° and 10° S.Lat, and with high mountains, its ecological diversity is analogous to, and exceeds, that of Hawaii.

The position of New Guinea in the SW Pacific makes it a key island for study of biota of the Pacific area, as well as a most logical area for comparison with Hawaii. As is generally accepted now, the large masses of Asian-Malaysian plant groups now found in New Guinea have arrived there by way of the large islands to the NW and W of New Guinea, such as the Philippines, Celebes and Borneo, while from New Guinea onwards many elements radiated out into the Pacific, ultimately reaching the Hawaiian Islands.

The backbone of New Guinea is formed by a WNW-ESE mountain system up to 200 km wide, with several peaks above 5000 m. Surrounding these ranges are flat, or slightly undulating, areas with scattered lower mountain ranges. Along the coasts in many areas extensive mangrove swamps are developed. In accordance with its position in the equatorial belt the climate is tropical with generally high rainfall, increasing with altitude but decreasing again in the higher subalpine and alpine regions. Temperature ranges from 33° in the lowlands to 4° - 6° C between 3500 and 4000 m, while on some of the highest peaks there are glaciers. Rainfall ranges from below 1000 mm in the dry Port Moresby area to 6400 mm in Ninati at 2500 m in the central ranges.

The vegetation is that of moist tropical rainforest in the lowlands with the exception of the dry savannas in the southern regions. In the lowlands (0 - 1200 m) it is rather heterogeneous in composition but in the midmontane forests (1200 - 2200 m) Fagaceae begin to dominate with conifer forests in the higher parts of this belt. In the montane forests (2200 - 3000 m) Ericaceae, Nothofagus and conifers dominate, while in the subalpine shrubberies (3300 - 4000 m) is a strong dominance of Ericaceae, Myrtaceae and conifers. In the alpine belt (4000 - 5000 m) the grasslands are the main feature, though the number of species composing these grasslands is rather low.

In view of New Guinea's position between the landmasses of Asia - Malaysia in the west, Australia in the south and the Pacific Islands to the north and east, the composition of its flora reflects those of the surrounding areas. Thus we find in most of the lower regions a tall rainforest composed mainly of Malaysian elements, while in the drier southern regions many Australian elements are found such as Eucalyptus and Tristania species. In the midmontane and montane belts there is still a strong dominance of Malaysian elements though in these belts the large endemic element in the New Guinea flora appears. In the subalpine and alpine regions elements from South America, New Zealand, Australia and the northern temperate areas form a large part of the vegetation together with a large endemic element. It is in these regions that one finds representatives of Viola, Euphrasia, Ranunculus and Parahebe, related to both elements of the northern and southern temperate and colder regions.

The main outline of the composition of the vegetation is relatively well known. The first description was by van Steenis, but that was incomplete, and in Dutch. The first overall description was by van Royen but that paper is in need of revision. Although from a descriptive standpoint the vegetation is relatively well known, this is by no means true from the ecological standpoint. The few papers that deal with an ecological view are still mainly descriptive and synecological, rather than analytical and autecological. In the first category belong all the papers of Brass on the various vegetations visited by him, and in the second an occasional paper like Walker's study of the Mt Wilhelm grasslands. The most important one is that by Wade and McVean on Mt Wilhelm, but this deals only with alpine grasslands in a limited scope.

For ecosystem studies in New Guinea a choice must be made because of the enormous size of the island, poor communications for many areas, and limitations on background information. For practical reasons, and for comparison with Hawaii, the start should be made in the midmontane forests. These are areas with cooler climate and provide better facilities. They are also areas with higher population levels and thus greater disruption of the environment. This will also provide interesting bases for comparisons with Hawaii. The abundance of people is partly related to less or no malaria and partly to great abundance of oaks, in turn providing greater abundance of pigs. From the applied standpoint these areas are also important for the potential production of lumber from Quercus and Nothofagus, as well as from conifers. Ecological studies are needed to develop an appropriate forestry policy. Most work done so far has been on Araucaria cunninghamii and A. klinkii (hunsteinii) in the Wau-Bulolo area.

Apart from the study of the midmontane and montane forests a study of the extensive grasslands in these belts plus those in the subalpine and alpine belts should be considered. Some attempts have been made to introduce cattle, and as far as sheep are concerned this turned out to be a failure. Better results were attained in the lowlands with dairy and meat cattle, expecially after introducing appropriate varieties. In the highlands there has been little success. Better knowledge has to be obtained of the composition and ecology of the grasslands under the prevailing climatic situation.

Placing emphasis on the ecological studies of the beech and oak-forests on the one hand, and the grasslands in the alpine, subalpine, midmontane and montane belts one has to take into consideration the best locality in which to start. In view of the existence of an alpine field station on Mt Wilhelm in the alpine grasslands, and the Wau Ecology Institute in the lower reaches of the midmontane forest, it is clear that this latter station has to be regarded as the base of operation. Around Wau extensive grasslands occur, but also oak and beech forests. Within two days walk there are alpine grasslands. Also, the Wau station is within a 300 km radius of extensive grasslands on Mt Wilhelm, the Finisterre Range, Mt Otto, the Sarawaket Range, the Owen Stanley Mts, etc, and can be used as a base for studies in these mountains, which can be reached directly in small aircraft from Wau. Thus a base and scope is provided for large teams of biologists for work over a long period.

The alpine station on Mt Wilhelm is small and usually a long waiting list for the facilities exists. Though for the study of the subalpine and alpine grasslands it is ideally situated, this shortage of facilities is a drawback. However, the station might be extended to provide more scientists an opportunity for studies. In some of the areas below the station there are grasslands, and around the Keglsugl airstrip - entry point by air for Mt Wilhelm - there are extensive beech and conifer forests. These are at the upper limit of the montane zone, whereas the Wau station is at the lower limit. The branch field station of the Wau Ecology Institute on the summit of Mt Kaindi is in the middle of the zone. This can be reached by vehicle from Wau in one hour.

The New Guinea fauna in general is not so well known or so well classified ecologically as is the vegetation. It is known that the greatest concentration of the endemic groups and the greatest general diversity of birds and mammals is in the montane zone, particularly upper mid-montane in the lower moss forests. This is certainly to a great extent true for insects and amphibians as well. The reptiles are more in evidence at lower altitudes. In general, the lowland species are widespread along the coastal strips, although many are confined to certain contrasting types of environments, such as tall rainforest, savanna, sago palm swamps, mangrove, nipa palm swamps, etc. Numerous localized species, and particularly members of the endemic genera, occur in different ranges in the mid-montane zone or in higher zones. Sometimes an unexpectedly large number of species may be found in a single group of animals within a modest range of altitude on one mountain. The faunal diversity is of course closely correlated with the diversity of flora, and the different vegetation types have characteristic fauna.

The zoogeographical relationships of the fauna are by no means uniform. The mammals include only the same four orders as in Australia, and the monotremes and marsupials are limited to Australia plus the Papuan Subregion. With the birds, there are strong Australian relationships, but also many close ties with SE Asia. This also applies to the reptiles. For the insects, however, relationships are much closer to SE Asia. Thus, mammalogists include the Papuan Subregion within the Australian Region, whereas many entomologists would place it in the Oriental Region. As with plants, the Polynesian forms usually relate to Papuan groups.

Summarizing, although New Guinea is much richer and more harmonic than Hawaii, many genera of plants and animals are possessed in common. One could propose various groupings of studies for comparisons with the Hawaiian ecosystems, such as comparing oak and beech forests with Metrosideros and Acacia koa forests (both in each case having many Araliaceae, Myrsinaceae, Liliaceae, Urticaceae, Rosaceae, Leguminosae and Rutaceae, and other elements in common). Further, comparisons of the analagous moss forests on the montane ridges and crests, as well as the various types of grasslands, would prove of great value. To carry out these studies it is suggested that the Wau Ecology Institute be used as the main headquarters and the Mt Wilhelm Research Station as a secondary base.

Research integration as a continuing mechanism for island ecosystems research

Study of the evolution of species does not necessarily require a multidisciplinary approach. Study of the evolution of ecosystems, however, cannot be accomplished without it. Moreoever, to obtain results of multidisciplinary research within a reasonable time, such research has to be integrated. Because our ultimate aim is to acquire knowledge of the evolution of island ecosystems and to communicate our findings not only to the scientific community but also to be effective in the management of the biological resources of islands, integration of our researches is essential.

Scientists, perhaps more than the average person, are individualistic by nature. This personality trait is often combined with originality and strong convictions in scientific matters. It certainly does not have to be combined with unwillingness to cooperate. The latter attitude cannot be tolerated in an integrated program.

Originality, as in individual research programs, is the most important personal asset in an integrated research program. An integrated program, therefore, has to be structured in such a way that it provides a sufficient scientific challenge for the individual researcher. This can be accomplished in two ways: (1) By arranging the scientific objectives in such a way that they provide a satisfactory challenge for each investigator on the program, (2) By selecting the right people to fill the important niches in the overall program.

In reality, an integrated research program is a compromise of the above two ways of structuring. However, the effectiveness of a program may be increased when moving closer to the second point. Elimination of an investigator from an integrated program does not necessarily mean that he is not a good researcher. It will mean more likely that his interests are not fulfilled in the niche that he originally opted for.

Adjustments in sub-objectives and research personnel are to be expected in any integrated research program as it develops to greater maturity. We do not consider ourselves as a permanent "in-group", but instead as a flexible coalition of researchers interested in the same ultimate aims.

An integrated approach to field biology and environmental problems, we strongly believe, is here to stay. A second important reason for increased effectiveness of the IRP approach is the continual and simultaneous information exhange through organized discussion, conversation, reporting and data exchange. A third reason is the sharing of facilities, which makes research considerably more economical. However, we also believe that"Big Biology" as initiated by IBP should not be the only form of research. Individual research programs should similarly be supported, where appropriate. Integrated research may fulfill many, but not all, research opportunities.

WORKSHOP MEETINGS

Four workshop meetings were held in 1971. The meetings served for announcing important news items, clarifying of logistic arrangements, reporting of progress and solving budget questions. Their main purpose was exchange of information and ideas and scientific coordination.

March 2, 1971 Meeting

A new name for our Program was announced: ISLAND ECOSYSTEMS STABILITY AND EVOLUTION Subprogram, or abbreviated, ISLAND ECOSYSTEMS IRP. The acronym IRP stands for Integrated Research Program. Originally, following the first program development meeting in March 1967, the Hawaii program was called HAWAII TERESTRIAL BIOLOGY PROJECT. The emphasis was on "terrestrial", because for several reasons it was concluded that the "cut-off point" should be the shoreline. The principle reason was that it is the terrestrial biota (in contrast to marine) that is most severely threatened in Hawaii. The new name indicates a shift in emphasis in line with our acknowledged status as an IRP.

A brief progress report was written for inclusion in a report of the ORIGIN AND STRUCTURE OF ECOSYSTEMS main program, of which our program is considered a subprogram. The report summarizes our objectives and strategy up to February 1971. The report is appended under SUPPLEMENTARY INFORMATION (item 1).

The discussion at the May 2 workshop meeting centered around an improved organizational ecosystem model for our transect studies. In particular, plans were made for integrated sampling along the Mauna Loa Transect. Four map sheets with relevé locations were distributed. The input and outcome of the meeting was summarized in a CIRCULAR LETTER, dated March 2, 1971. The circular letter is appended as item #2 under SUPPLEMENTARY INFORMATION (The originally attached map sheets were omitted here to save in duplicating costs).

May 6, 1971 Meeting

A call for further thought-input was made at the preceding meeting and in the March 2 circular letter. Responses in form of brief information sheets were distributed to each participant at this meeting. The information sheets related to established sampling locations along the Mauna Loa Transects, to brief accounts of sampling results and to interaction models as emerging from the study of certain groups of organisms. Since most of this information is incorporated into the individual annual progress reports enclosed in this volume, the information sheets are not attached. An evolutionary interpretation to a correlated sampling effort was presented, which was subsequently summarized in a CIRCULAR LETTER, dated May 23, 1971. The circular letter is appended as item #3 under SUPPLEMENTARY INFORMATION.

Dr. W. W. Milstead, Scientific Coordinator of the Environmental Programs of the US/IBP, visited us at the May 6 meeting. He presented a brief slide-show emphasizing activity high lights of other US/IBP programs.

October 8, 1971 Meeting

This meeting, which followed the inter-smester field season, was a full-day annual review symposium. Nineteen papers were presented by a majority of our IBP participants. Ample time was allowed for discussion and exchange of ideas. The outline of the October 8 workshop symposium is enclosed as information item #4 under SUPPLEMENTARY INFORMATION. Each speaker produced a one- or two-page information sheet summarizing his main points. This was xeroxed and distributed to each symposium participant. The main information in these papers was incorporated into the reports shown under PROGRESS OF INDIVIDUAL SUB-PROJECTS. An additional paper (not listed on the symposium agenda) was presented by Dr. Gordon D. Wallace. His abstract is enclosed as item #5 under SUPPLEMENTARY INFORMATION.

December 9, 1971 Meeting

This meeting was called for a discussion of developments in the overall US/IBP that expired from the Annual Meeting of the US/IBP National Committee at Oak Ridge. A report on that meeting was distributed to all Hawaii IBP participants prior to our December 9 workshop meeting. It is enclosed as item #6 under SUPPLEMENTARY INFORMATION. Two other major objectives of the December 9 meeting were discussion of our third-year budget plans and our more immediate and ultimate program aims. The latter are presented in detail in the first chapter of this report under AIMS OF ISLAND ECOSYSTEMS PROGRAM.

INTEGRATION OF RESEARCH TASKS

In the course of last year's activity several more closely interacting groups of researchers in our program were beginning to cluster around certain areas of major emphasis. These are related to the recently established Inter-Biome Committees. But we have evolved into certain additional areas of emphasis, and we are as yet rather weak in some of the areas represented by the Inter-Biome Specialist Committees.

Specialist Committees

During the summer of 1971, the US/IBP Environmental Component under the coordination of Dr. Milstead made a move to establish so-called "specialist committees", whose aim is integration of certain subject areas across the various US ecosystems IRPs. Eight areas were established for this purpose. These are:

1. Storage and retrieval
2. Modelling
3. Phenology
4. Nutrient cycling
5. Decomposition
6. Meteorology
7. Consumer processes and
8. Primary productivity.

We were asked to name a representative and an alternate from our program for each of these areas. A memorandum of September 7, 1971 (attached as item #7 under SUPPLEMENTARY INFORMATION) shows our representatives on seven of the eight specialist committees.

Since then, five of these committees had meetings. What expired from each of these meetings was reported by our representatives, and their reports are under SUPPLEMENTARY INFORMATION as:

Item # 8 Dr. C. H. Lamoureux: Phenology.

Item # 9 Mrs. Ruth Gay: Modelling.

Item # 10 Dr. D. J. C. Friend: Primary Productivity.

Item # 11 Dr. P. C. Ekern: Meteorology.

The first specialists meeting of the Storage and Retrieval Committee took place in June before our program was represented.

A list of membership on the Environmental Programs' Specialist Committees was distributed by Dr. Milstead. This is enclosed as item # 12.

Areas of emphasis in the Island Ecosystems IRP

The areas summarized below have developed from the research topics and interests of the principal investigators on our program. Their clustering has become evident through discussion, reporting, and interaction in field work.

I. Community approach

1.	*Seasonal phenomena related to phenology; population fluctuations of short-lived organisms (insects, leaf-fungi, soil algae)	Lamoureux, Nishida & Haramoto, Beardsley, Conant, Baker, Doty, Gagné
2.	*Consumer processes (here firstly included insects only; in soil, water, bark, stem, branches, leaves)	Delfinado, Radovsky, Gagné, Nishida, Howarth, Samuelson
3.	*Meteorology and micro-environmental studies, radiation and water budgets, (soil environment)	Ekern, Friend, Mueller-Dombois, Tieszen (next year)
4.	Ecosystem structure, large herbivore impact, stability as related to perennial (long-lived) organisms, rodents, birds	Mueller-Dombois, Friend, Tomich, Berger

*Areas indicated by an asterisk are those presently represented by inter-biome specialist committees. Perhaps, we have the remaining five areas in common with the other two ORIGIN AND STRUCTURE OF ECOSYSTEMS SUBPROGRAMS, the Desert and Mediterraenean Scrub programs. It can be seen that many of us work across several areas. Therefore, close integration exists also between the 10 fields of emphasis.

5.	Reproduction cycle of ecosystem structure-forming plants, interferences, pollination, seed feeders	Nishida, Corn, Lamoureux, Mueller-Dombois, Tomich, Gagne, Hirashima (insect pollinators; 3rd year), Mitchell (seed feeding insects; 3rd year)
6.	*Decomposition, primary production	Baker, Friend, Tieszen (3rd year), Mueller-Dombois. We are as yet very weak in this area, because we did emphasize in our Feb. '70 proposal that turn-over studies will be postponed

II. Population approach

7.	Speciation, genecology in field environments	Hardy, Carson, Paik, Corn, Gressitt, Berger, Lamoureux, Steffan, Howarth
8.	Laboratory verification studies on speciation by electrophoresis and chromosome analysis	Ashton, Carson, Paik, Steiner
9.	Physiological ecology experiments to assess degrees of evolutionary adaptation	MacMillan, Friend, Mueller-Dombois Corn, Tieszen (3rd year)

III. Synthesis

10.	*Modelling group, to interact with all coordinated subjects; Data storage and retrieval	Mi, Gay, Liang, Yamashiro, Mueller-Dombois

The first named person for each field of emphasis is the current scientific coordinator of that group. The above tabulation of themes and personnel is not considered to be an inflexible, permanently fixed grouping.

As we move along, we may expect certain adjustments. For example, it may well be that the coordinator's or committee chairman's position will transfer to another person in that group, or that someone else may enter a new group.

Organizational structure of Island Ecosystems IRP

Because of the increased attention to detail required in each area of emphasis, it will not be practical anymore for one person to do the scientific coordination for all individuals on our program. Instead we now have 10 Scientific Coordinators or "theme chairmen" plus a Site Coordinator. Because of increased administrational commitment, we are asking for a position of an Assistant Director for the third year. These decisions were made at a co-director's meeting on December 22, 1971.

The new organizational structure is outlined below:

ISLAND ECOSYSTEMS IRP
(organizational structure)

Advisory Panel:
Ashton, Hardy,
Lamoureux, Fosberg

Director:
Mueller-Dombois

Co-directors:
Berger
Gressitt

AdministrativeAssistant
and secretary:
Mrs. L. Fuller

Assistant Director:
Modeller:
Mrs. R. Gay

Site Coordination; Field logistics; Vehicle maintenance; Climatic Stations:
Jacobi

Scientific Coordinating Committee Chairmen:
Lamoureux, Delfinado, Radovsky, Ekern, Mueller-Dombois, Nishida, Baker
Friend, Hardy, Ashton, MacMillan, Mi

Subject Areas: 1-10

Individual Investigators

New projects and personnel

No major additions to the existing group of subprojects were anticipated for the third year. However, we are asking for inclusion of subproject C-11 "Insect interference in the reproduction cycle of community-structure forming plants, particularly seed feeders." This subproject will be carried out by Dr. W. C. Mitchell. Subproject C-11 was included already in our funded February 1971 proposal. It was not yet activated because of lack of funds. The orientation of this subproject has been broadened for better integration with the overall project aims. The revised C-11 proposal is included as item #13 under SUPPLEMENTARY INFORMATION.

Another first-year included, but not yet funded subproject was B-9 "Bryophytes, their distributional dynamics in Hawaiian ecosystems" (Vaarama). We are asking that this subproject be included for the 3rd year as it fills an important gap.

As explained under AIMS OF ISLAND ECOSYSTEMS IRP we intend to devote a greater share of our efforts to regional problems. For this reason we are asking for a new postdoctoral position under subproject D-2 (P. Q. Tomich) to activate a behavioral study of the feral goat. For the same reason we like to strengthen our basic research on Acacia koa, the most valuable Hawaiian forest tree species. A study of photosynthesis and respiration patterns of this species by Dr. Larry M. Tieszen will also greatly strengthen inter-program coordination in primary productivity, since Tieszen has worked on this aspect in the Tundra Biome. Dr. Tieszen's study is intended as part of subproject B-4, "Studies on the autecology of important trees." His proposal is attached as item # 14 under SUPPLEMENTARY INFORMATION.

Expansion is anticipated in our modelling efforts. For this reason we have included two additional personnel, Dr. T. Liang, Assoc. Professor in Agricultural Engineering and Mrs. Ruth Gay, Instructor in Botany, both from the University of Hawaii. Mrs. Gay is also suggested for functioning as Assistant Director.

The curriculum vitae of Dr. Liang is enclosed as item # 15 and that of Mrs. Gay as item # 16 under SUPPLEMENTARY INFORMATION.

SITE COORDINATION

The six IBP transects on Hawaii

Fig. 1 shows the six transects on the Island of Hawaii, along which nearly all of our field work is concentrated at the present time. Their location names are as follows:

Transect-Profile 1	Mauna Loa - Thurston Lava Tube
Transect-Profile 2	Kilauea Forest - Hilini Pali
Transect-Profile 3	Olaa Forest - Apua Point
Transect-Profile 4	Naulu Forest - Kealakomo
Transect-Profile 5	Kalapana lowland
Transect-Profile 6	Mauna Kea

Transects 1-5 are mostly inside Hawaii Volcanoes National Park. The vegetation of the Park was mapped on 1:12,000 air photographs. The ecosystems along the transects were defined on the basis of vegetation structure, but also by climate and substrate. This is indicated on the following six profile diagrams (Figs. 2-7), which also show the topographic position and extent of each ecosystem and the length of each transect in miles. The transects are interpreted as broad belts. This means that each ecosystem, designated by a segment number on each transect-profile diagram, has a width of at least half a mile. But in most cases the type of ecosystem extends for several miles across each transect. Their exact outlines are defined on the air photo vegetation map*. Recent lava flow vegetation was omitted because of their limited geographic extent along these transects.

Recent changes caused by lava flows

However, since 1968 Transect 3 (Fig. 4) has become partly inaccessible because of massive new lava flows that extruded from the Aloi and Alae Crater areas southward into the sea. On the map (Fig. 1), the source of the lava outpour is in the circle of number 3. On Transect-Profile 3 (Fig. 4), this refers to the destruction of the westward parts of the ecosystems from segment 1 through 7. Similarly, the northern portion of transect 4 (Fig. 5) has become inaccessible. Naulu Forest (segment 4) became inaccessible in 1971. It is not destroyed, but the access road became blocked by lava. Therefore, IBP sampling in 1971 was restricted more or less to ecosystems along Transects 1, 2 and 5.

Ecosystems along the transects

The ecosystems along transects 1-5 were described briefly in the Atlas for Bioecology Studies in Hawaii Volcanoes National Park (Doty and Mueller-Dombois 1966). The ecosystems along transect 6 were described by Mueller-Dombois and Krajina (1968). Here, only brief reference will be made by giving a name for each segment along the transects. The ecosystem names stated below are strictly pragmatic and not systematic.

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*One set of 53 (27 x 27 inch) air photo sheets with plastic vegetation and topographic overlays are kept in the USDI library at Hawaii Volcanoes National Park Headquarters.

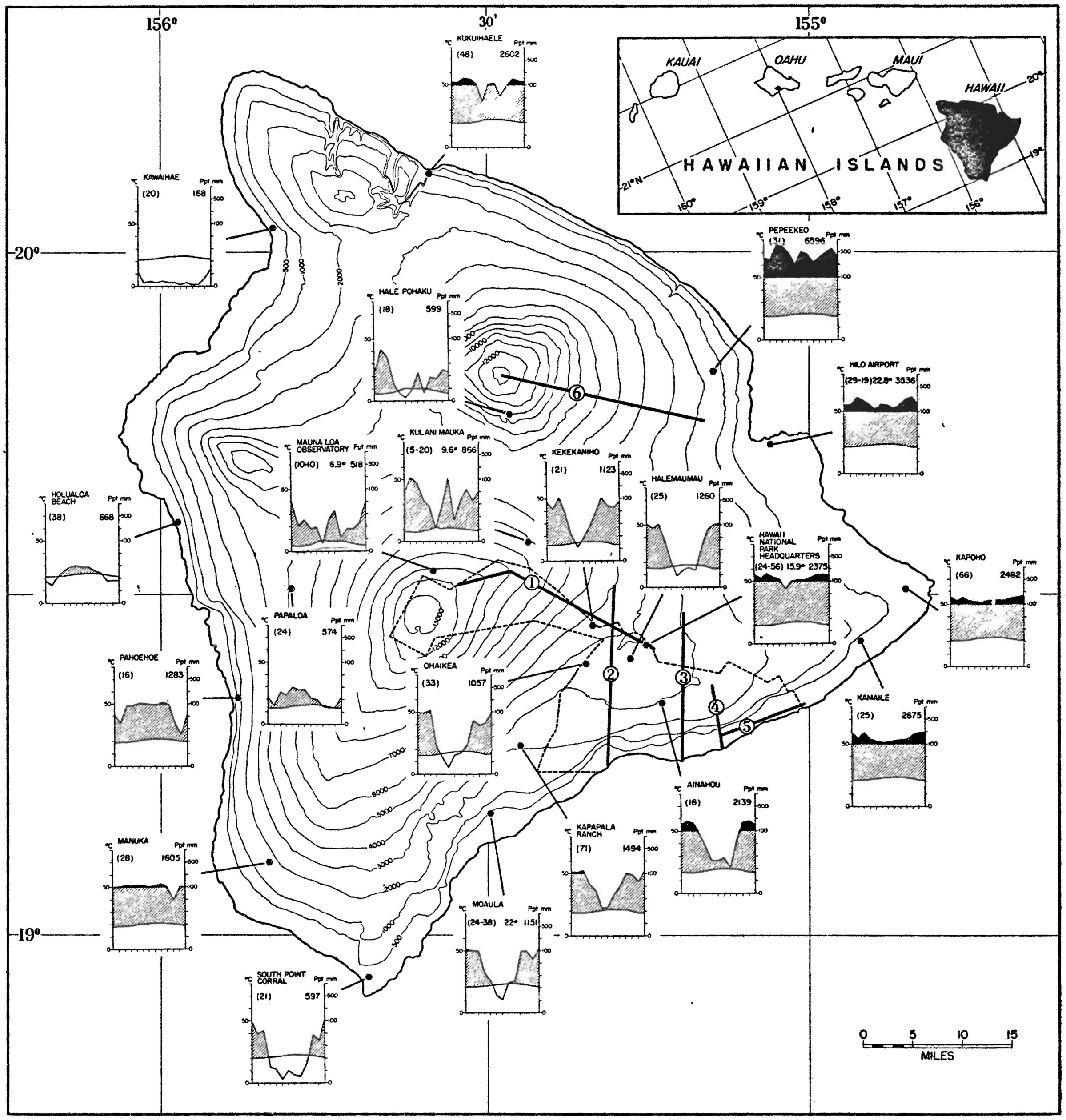


Fig. 1. Orientation map of Hawaii showing location of IBP transects 1-6. The Kilauea rain forest study site is at the north end of transect 2. Dashed lines show outline of Hawaii Volcanoes National Park. IBP field quarters are near the east end of transect 1. The diagrams show mean monthly rainfall (mm) and temperature (^{o}C) curves plus mean annual rainfall of 21 weather stations.

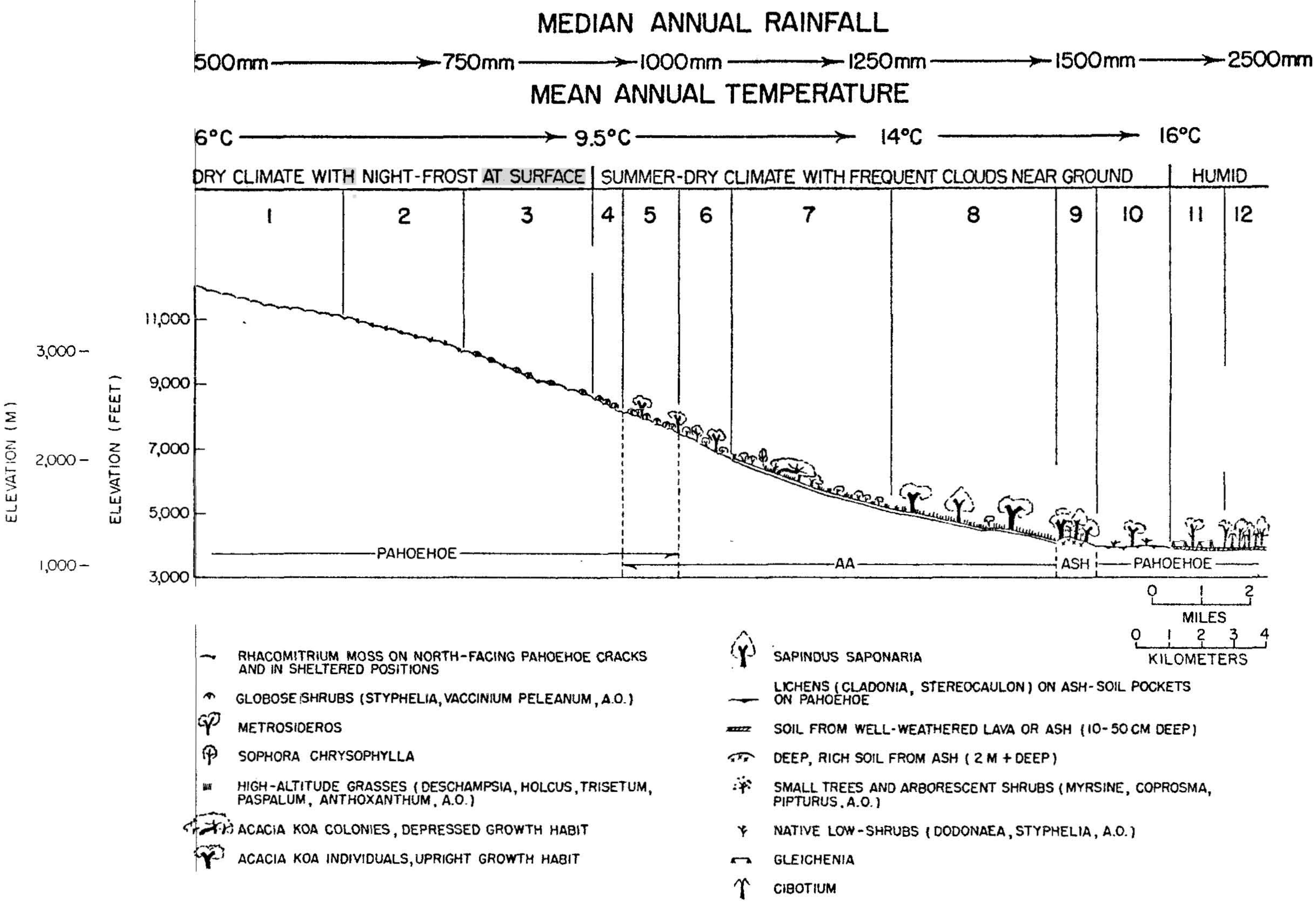


Fig. 2. Transect-profile 1, Mauna Loa - Thurston Lava Tube. Ecosystem types on the east-flank of Mauna Loa from 12,000 feet down to 3900 feet on prehistoric and dominant substrates, 22 miles, starting from Ohaku O Hanalei over Puu Ulaula, Kipuka Puaulu (segment 9) to Kilauea Iki surroundings.

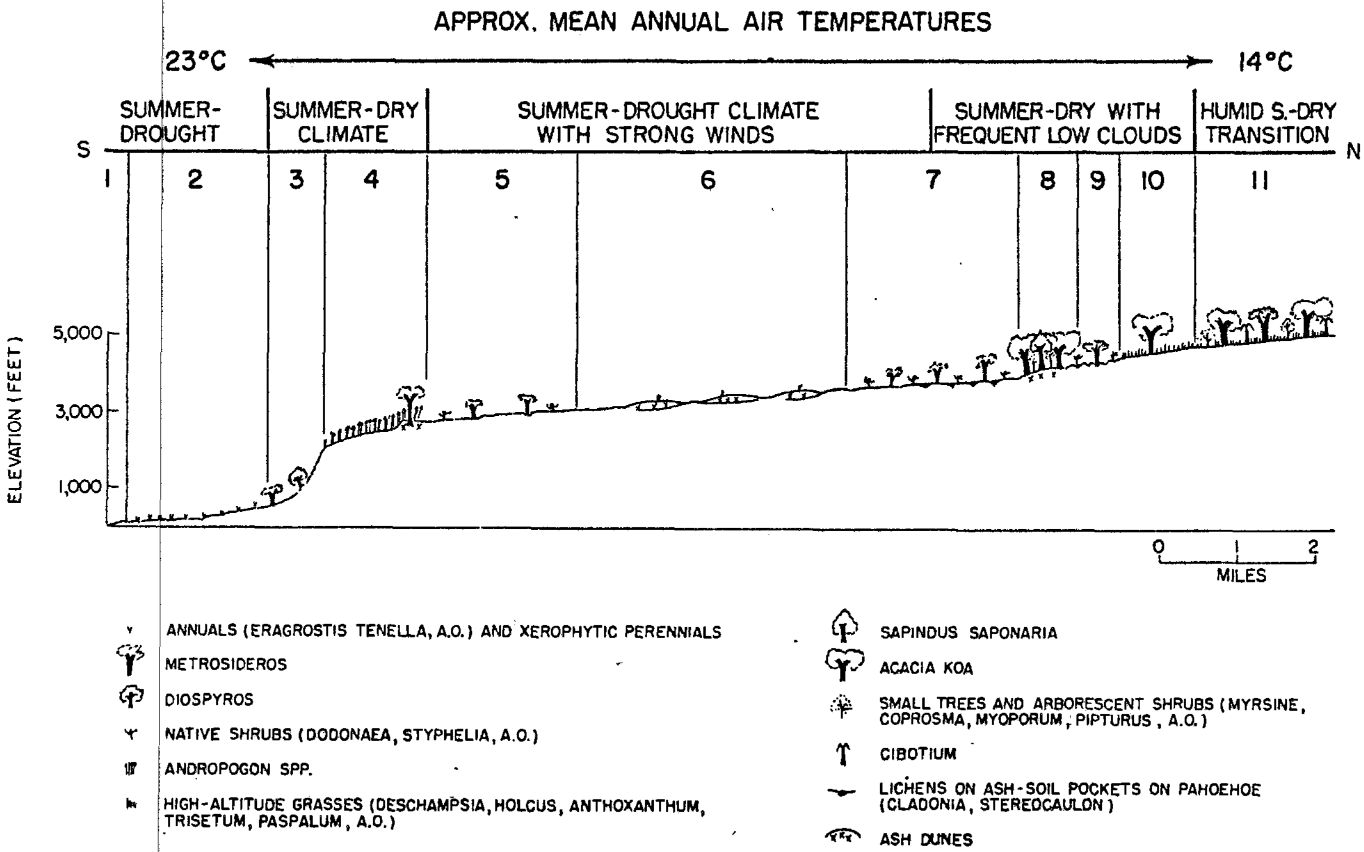


Fig. 3. Transect-profile 2, Kilauea Forest - Hilina Pali. Ecosystem types along south-north transect in the west-central area of Hawaii Volcanoes National Park from sea level to 5000 feet, i.e., for 17 miles from the shore (segment 1) through Hilina Pali (segment 3), the Kau Desert (segment 6) and Kipuka Puaulu (segment 8) to the Kilauea Forest Reserve (segment 11).

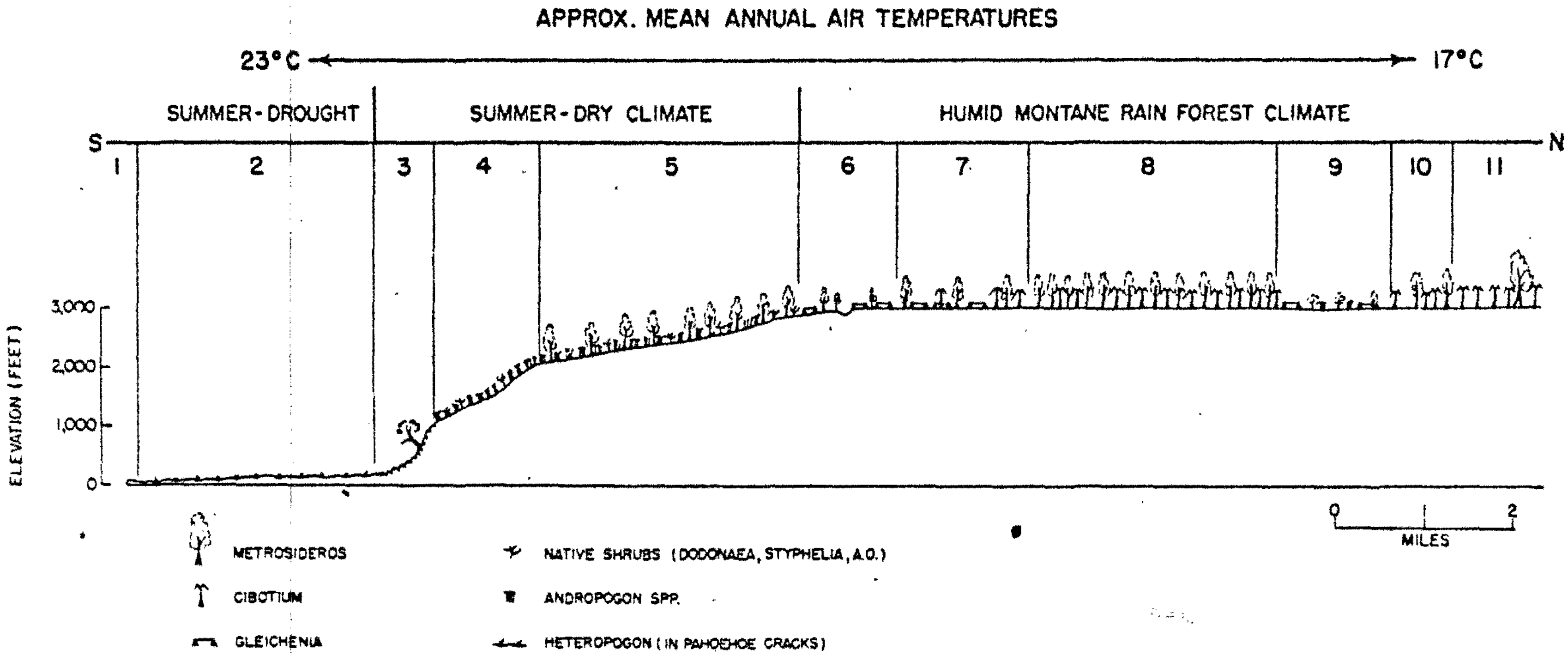


Fig. 4. Transect-profile 3, Olaa Forest - Apua Point. Ecosystem types along south-north profile in east-central area of Hawaii Volcanoes National Park from sea level to 3,000 feet, 16 miles, from Apua Point, passing by Ainahou Ranch area (segments 4 and 5), through Alae Crater (segment 6) to Olaa Forest Reserve (segments 10 and 11). The eastern parts of ecosystems 1 through 7 were recently destroyed by new lava flows.

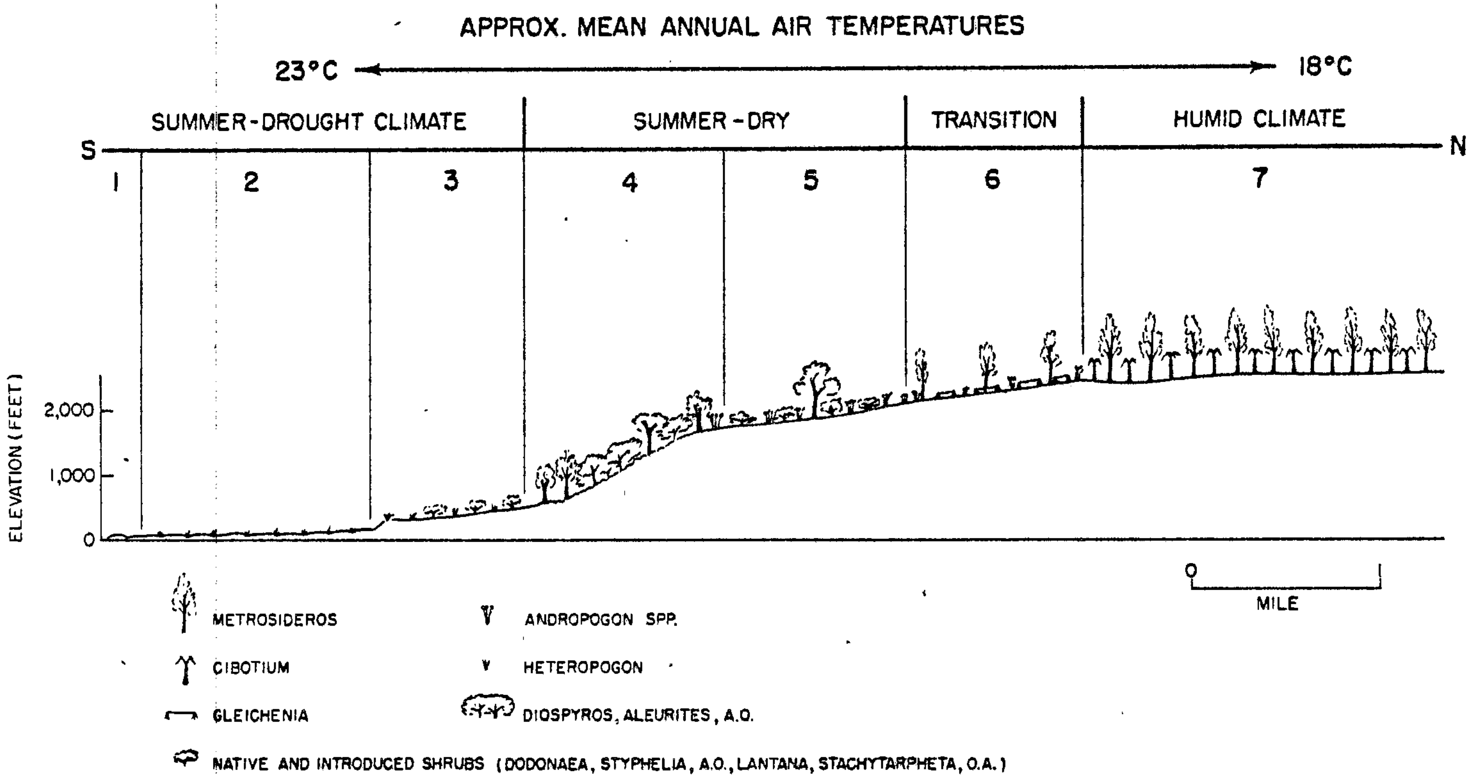


Fig. 5. Transect-profile 4, Naulu Forest - Kealakomo. Ecosystem types along south-north profile in the eastern area of Hawaii Volcanoes National Park from sea level to 2500 feet, a transect 7 miles long extending from Kealakomo (segments 1 and 2) through Naulu Forest (segment 4) to Napau Crater area (segment 7). Segments 4 to 7 are accessible only by helicopter.

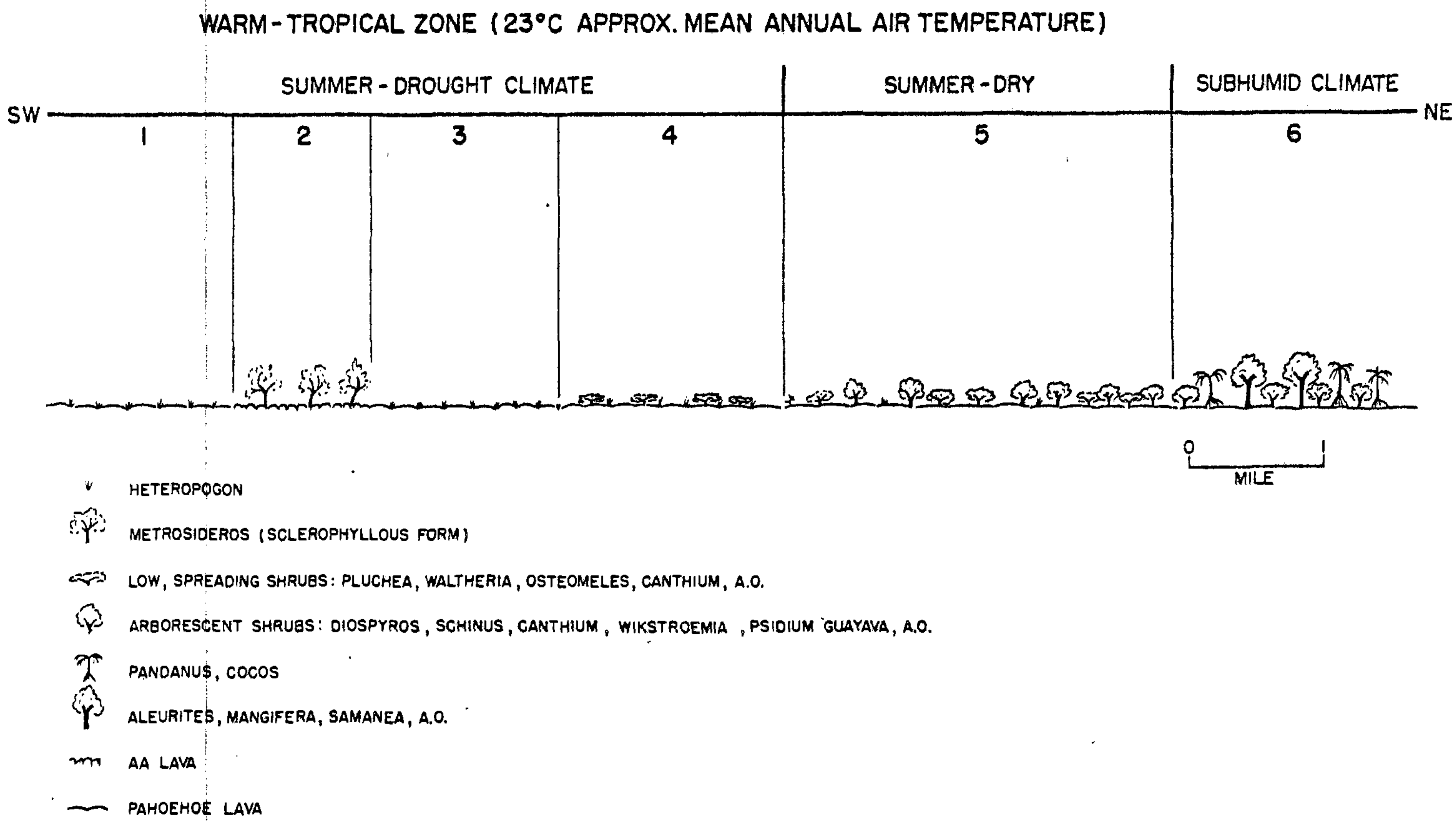


Fig. 6. Transect-profile 5, Kalapana lowland. Ecosystem types in the eastern lowland of Hawaii Volcanoes National Park. Transect extends from Kaena (SW) to Kalapana (NE) over a distance of 10 miles at elevations between 30-60 feet above sea level.

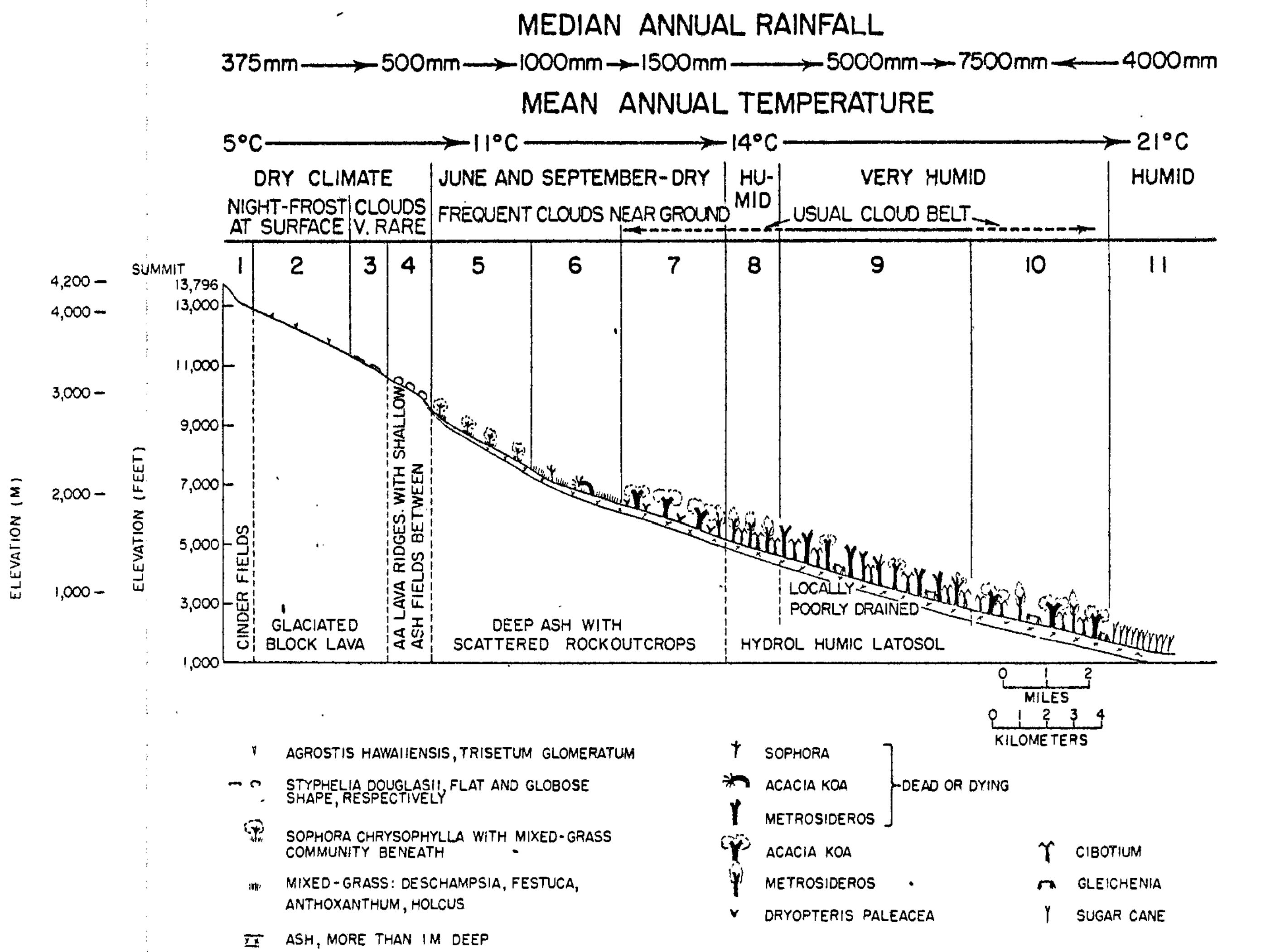


Fig. 7. Transect-profile 6, Mauna Kea. Ecosystem types along the east-flank of Mauna Kea from summit down to 1300 feet towards Hilo Bay. Transect is 21 miles long and runs over Puu Akala between Aweh and Hanollii Streams to above Kaiwiki School.

Transect-Profile (TP) 1 (Fig. 2) Mauna Loa east-flank

TP 1	Segment 1	Alpine stone desert
TP 1	Segment 2	Rhacomitrium moss desert
TP 1	Segment 3	Vaccinium-Styphelia low-scrub desert
TP 1	Segment 4	Alpine aggregate-scrub
TP 1	Segment 5	Metrosideros tree line ecosystem
TP 1	Segment 6	Open subalpine Metrosideros-Sophora scrub-forest
TP 1	Segment 7	Mountain parkland ecosystem (formed by Acacia koa (koa) tree colonies, Styphelia-Dodonaea tall-scrub communities, both in a matrix of subalpine grassland)
TP 1	Segment 8	Koa savanna ecosystem
TP 1	Segment 9	Closed kipuka forest (segment 9 interdigitates locally with 8)
TP 1	Segment 10	Open Metrosideros - lichen forest with low shrubs on shallow ash over pahoehoe
TP 1	Segment 11	Open Metrosideros - matted fern (Dicranopteris = Gleichenia) forest on shallow ash over pahoehoe
TP 1	Segment 12	Closed Metrosideros - tree fern (Cibotium spp.) montane rain forest

Transect-Profile 2 (Fig. 3) Kilauea Forest-Hilina Pali

At the north end, this transect-profile begins in our intensive research site, in the Kilauea montane rain forest (segment 11).

TP 2	Segment 1	Salt-spray communities on lava rock
TP 2	Segment 2	Annual (Eragrostis tenella) grassland
TP 2	Segment 3	Very open Metrosideros-Diospyros forest on rock-rubble and aa lava
TP 2	Segment 4	Perennial (Andropogon glomeratus and A. virginicus) grassland
TP 2	Segment 5	Very open Metrosideros scrub-forest on pahoehoe
TP 2	Segment 6	Extremely sparse desert vegetation (Kau ash-dune desert)
TP 2	Segment 7	Open Metrosideros - lichen forest with low shrubs on shallow ash over pahoehoe (same as transect 1, segment 10)

TP 2 Segment 8 Closed kipuka forest (Kipuka Puaulu; same as transect 1, segment 9)

TP 2 Segment 9 Open Metrosideros - native shrub forest on aa (note, similar to segment 7, but substrate is different)

TP 2 Segment 10 Pasture ecosystem with scattered koa (cattle ranchland north of National Park boundary)

TP 2 Segment 11 Acacia koa - Metrosideros - tree fern (Cibotium spp.) forest (our 200-acre IBP study site in Kilauea Forest Reserve, owned by Bishop Estate, is located here. This forest is protected by a fence from invasion of cattle from the neighboring ranchland).

Transect-Profile 3 (Fig. 4) Olaa Forest-Apua Point

TP 3 Segment 1 Same as TP 2 Segment 1

TP 3 Segment 2 Perennial (Heteropogon contortus) grassland

TP 3 Segment 3 Same as TP 2 Segment 3

TP 3 Segment 4 Same as TP 2 Segment 4

TP 3 Segment 5 Open Metrosideros-Andropogon forest with native shrubs on shallow ash over pahoehoe (seasonal Metrosideros montane forest)

TP 3 Segment 6 Open Metrosideros scrub-forest with interdigitated matted fern (Dicranopteris) and grass (Andropogon spp.) patches (now largely destroyed by recent lava outpour)

TP 3 Segment 7 Open Metrosideros-Cibotium-Dicranopteris fern forest (now largely destroyed in this area)

TP 3 Segment 8 Closed Metrosideros - tree fern (Cibotium spp.) forest, same as TP 1 Segment 12

TP 3 Segment 9 Same as TP 3 Segment 6, but not destroyed. Also similar to TP 1 Segment 11.

TP 3 Segment 10 Open Metrosideros-Cibotium forest (structurally similar to TP 3 Segment 7 except for stocking density of Metrosideros), Olaa Forest

TP 3 Segment 11 Cibotium forest with scattered old Metrosideros trees laden with epiphytes and woody lianas (Freycinetia arborea). Olaa Forest

Transect-Profile 4 (Fig. 5) Naulu Forest- Kealakomo

TP 4	Segment 1	Same as Segment 1 on TP 2 and TP 3
TP 4	Segment 2	Same as TP 3 Segment 2
TP 4	Segment 3	Perennial (*Heteropogon*-*Tricholaena*-*Andropogon*) grassland with shrubs scattered throughout = low-shrub savanna
TP 4	Segment 4	*Metrosideros*-*Diospyros* forest with patchy stands of *Aleurites moluccana* (kukui) = mixed dry evergreen forest with very sparse undergrowth. Naulu Forest
TP 4	Segment 5	Scrub with grass (*Andropogon* spp.) and scattered *Metrosideros* trees
TP 4	Segment 6	Open *Metrosideros* forest with matted fern (*Dicranopteris linearis*) and perennial grass (*Andropogon virginicus*) in overlapping patches (similar to TP 3 Segment 6)
TP 4	Segment 7	Closed *Metrosideros*-*Cibotium* rain forest (same as TP 3 Segment 8 and TP 1 Segment 12). Makaopuhi-Napau Crater forest. Presently inaccessible, except by helicopter.

Transect-Profile 5 (Fig. 6) Kalapana lowland

TP 5	Segment 1	Perennial (*Heteropogon contortus*) grassland on pahoehoe; very sparse grass cover. Same as TP 3 Segment 2 and TP 4 Segment 2.
TP 5	Segment 2	Scattered *Metrosideros* trees on nearly barren aa lava = rockland savanna. Similar to TP 2 Segment 3 and TP 3 Segment 3, except that the latter are on steep slopes and are stocked with more *Diospyros ferrea* trees.
TP 5	Segment 3	Same as TP 5 Segment 1, but *Heteropogon* less sparse.
TP 5	Segment 4	Low-shrub savanna. Same as TP 4 Segment 3.
TP 5	Segment 5	Mixed lowland scrub (contains a number of small native tree species--*Canthium odoratum*, *Wikstroemia phillyraefolia*, *Diospyros ferrea*, *Metrosideros collina* subsp. *polymorpha*)
TP 5	Segment 6	Mixed lowland forest (comprised mainly of introduced trees *Mangifera indica*, *Samanea saman*, *Cocos nucifera*, *Pandanus*, *Thespesia*, *Aleurites moluccana*). Near village of Kalapana and outside of Park boundary.

Transect-Profile 6 (Fig. 7). Mauna Kea east-flank

TP 6	Segment 1	Alpine stone desert with occasional crustose lichens
TP 6	Segment 2	Perennial (*Agrostis sandwicensis*, *Trisetum glomeratum*) grass desert, extremely sparse cover
TP 6	Segment 3	*Styphelia* low-scrub desert. Homologous to TP 1 Segment 3
TP 6	Segment 4	Scattered, globose *Styphelia* scrub
TP 6	Segment 5	*Sophora* tree line ecosystem
TP 6	Segment 6	Ranch grassland with scattered dying *Sophora* and *Acacia koa* trees. Analogous to TP 1 Segment 7
TP 6	Segment 7	Open *Acacia koa*-*Metrosideros* upper montane forest with herbaceous fern (*Drypteris paleacea*) in undergrowth.
TP 6	Segment 8	Closed *Metrosideros*-*Cibotium* rain forest. Homologous to TP 1 Segment 12
TP 6	Segment 9	*Metrosideros*-*Cibotium*-*Dicranopteris* forest with dying patches of *Metrosideros*. (This is the dying ohia forest currently investigated by U.S. Forest Service.)
TP 6	Segment 10	*Acacia koa*-*Metrosideros*-*Cibotium*-*Dicranopteris* lower montane rain forest
TP 6	Segment 11	Sugarcane fields above Hilo

Distribution of IBP sampling locations and study sites

Table 1 provides for an overview of the 1971 ECOSYSTEMS IBP activities along the six transects. The table is a summary abstracted from individual progress reports. The tabulation was supplemented, where additional information was available. However, Table 1 is not necessarily complete, nor does it pretend to be. It provides a basis for updating in the near future.

The two main study sites where nearly all investigators convened, are the Mauna Loa Transect (transect 1) and the Kilauea rain forest (transect 2), segment 11). More detailed information on sampling locations is found under PROGRESS OF INDIVIDUAL SUBPROJECTS.

Table 1. Distribution of sampling locations by subprojects and ecosystems along the IBP transects

Project code	Investigators	Research topic	Sampling location (elevation in feet)	Transect No.	Segment No. (ecosystem)
A-1	Hardy, Carson	Drosophila project	5300 Kilauea forest	2	11
			4000 Olaa forest	3	10
B-1	Mueller-Dombois Spatz	Gradient analysis	100 relevés from 4000-10050	1	2-9
B-1	Mueller-Dombois Spatz	Herbivore study	6200 Strip Road	1	7
			6000 Strip Road	1	7
			5400 Strip Road	1	7
			5300 Climatic Station	1	7
			1000 Kukalauula	2	2
B-2	Mueller-Dombois Cooray, Craine	Tree population structure, plant synusiae	5400 -5200 Kilauea forest along 4 TR's	2	11
B-3	Lamoureux Porter	General tree phenology	6700 End Strip Road	1	7
			6000 Strip Road	1	7
			5400 Kilauea forest	2	11
			5150 Strip Road	1	7
			4000 Kipuka Puaulu	1	9
			4000 Military Camp	1	11
			4000 Thurston Lava Tube	1	12
			3000 Kipuka Nene	-	-
			25 Kalapana	5	5
		Metrosideros phenology	7000 Summit Trail	1	6
			5150 Strip Road	1	7
			4120 Kipuka Ki	1	9
			4025 Highway 11	-	-
			3990 Strip Road	1	10
			3920 Thurston Lava Tube	1	12
			3370 Hilina Pali Road	3	5
			2380 Hilina Pali	2	4
			50 Kalapana	5	2
B-4	Spatz Mueller-Dombois	Koa growth rates	5400 Kilauea forest	2	11
			4200 Kipuka Puaulu	1	9
		Koa reproduction study	6650 End of Strip Road	1	7
			5400 Kilauea forest	2	11
			5300 Climatic Station	1	7
			4200 Kipuka Ki	1	8
	~~Mueller-Dombois~~ Spatz, Cooray	~~Metrosideros~~ (ohia) frost resistance	~~8000 Summit Trail~~	~~1~~	~~5~~
			4000 Quarter 201	1	12
B-5	Friend Becker	Tree fern ecology	5400 Kilauea forest	2	11
B-6	Corn	Metrosideros genecology	6600 End of Strip Road	1	7
			3900 Thurston Lava Tube	1	12
			Saddle Road	-	-
			Maui	-	-
			Kauai	-	-
			Oahu	-	-

Table 1. Distribution of sampling locations by subprojects and ecosystems along the IBP transects (continued)

Project code	Investigators	Research topic	Sampling location (elevation in feet)	Transect No.	Segment No. (ecosystem)
B-7	Doty McGurk	Algal ecology	10000-4000	1	3-9
			Hilina Pali Road (2 sites)	2	?
			Thurston Lava Tube	1	12
			Kalapana Coast	5	?
B-8	Baker Dunn	Fungal communities on tree leaves	8250 Summit Trail	1	5
			7250 Summit Trail	1	6
			6250 Strip Road	1	7
			5400 Kilauea forest	2	11
			5250 Strip Road	1	7
			4250 Strip Road	1	8
			3250 Hilina Pali Road	3	5
			2250 Hilina Pali	2	4
C-1	Hardy Delfinado	Diptera study	6500 Wailuku Stream	6	6
			4790 Wailuku Stream	6	8
			4140 Wailuku Stream	6	9
			2720 Wailuku Stream	6	9
			2040 Wailuku Stream	6	10
			1270 Wailuku Stream	6	11
			900 Wailuku Stream	6	11
			500 Wailuku Stream	6	11
			50 Wailuku Stream	6	11
			Kohala Mountains	-	-
C-2	Steffan	Sciaridae ecology	5400 Kilauea forest	2	11
			5300 Climatic Station	1	7
C-3	Gressitt Davis	Cerambycid bark beetles	5400 Kilauea forest	2	11
			5300 Climatic Station	1	7
			4200 Kipuka Ki	1	9
			West Maui	-	-
C-4	Gagné	Phytophagous insects, sap and seed feeders	7000 Summit Trail	1	6
			6600 End of Strip Road	1	7
			5400 Kilauea forest	2	11
			4000 Strip Road	1	8
			3900 Thurston Lava Tube	1	12
			3900 Hilina Pali Road	3	5
			2500 Hilina Pali	2	4
			25 Kalapana	5	?
C-5	Beardsley Leeper	Koa psyllid ecology	6600 End of Strip Road	1	7
			5300 Climatic Station	1	7
			4300 Kipuka Ki	1	8
			3000 Kohala Mountains	-	-

Table 1. Distribution of sampling locations by subprojects and ecosystems along the IBP transects (continued)

Project code	Investigators	Research topic	Sampling location (elevation in feet)		Tran-sect No.	Segment No. (ecosystems)
C-6	Nishida Haramoto Nakahara	Insect communities on Metrosideros leaves, branches, bark, litter	8000 (11)*	Summit Trail	1	5
			7000 (16)	Summit Trail	1	6
			5500	Strip Road	1	7
			4000 (18)	Strip Road	1	10
			3800 (1)	Strip Road	3	5
			3500	Hilina Pali Rd.	3	5
			3400	Hilina Pali Rd.	3	5
			500	Kalapana, uphill	5	2
C-9	Radovsky Samuelson	Soil and Litter arthropods	8000 (11)		1	5
			7500 (15)		1	5
			7000 (16)		1	6
			6800 (17)		1	6
			6200 (24)		1	7
			5400	Kilauea forest	2	11
			5350 (94)		1	7
			5100 (21)		1	7
			4400 (40)		1	8
			4200 (39)		1	9
			4050 (38)		2	9
			4000 (18)		1	10
			3950 (19)		1	8
C-12	Conant Tamashiro	Diseases on endemic insects (Uresiphita)	6700	End of Strip Rd.	1	6
			6400	Pohakuloa	-	-
			5300	Saddle Road	-	-
			5000	Strip Road	1	7
			4300	Kipuka Ki?	1	8
			1900	Hualalei	-	-
D-1	Berger	Evolution of honey-creepers	5400	Kilauea forest	2	11
				Sophora forest	6	5
				Kauai	-	-
D-2	Tomich	Rodent ecology	5400 5200	Kilauea forest (all 4 TR's)	2	11
			7000 - 4000	9 sites at relevés	1	6-9
E-1	Paik Sung	Drosophila genecology	6700	End of Strip Rd.	1	6
			6100	Strip Road	1	7
			5400	Kilauea forest	2	11
			5110	Strip Road	1	7
			4300	Strip Road	1	8
			4000	Strip Road	1	8
				Oahu (3 sites)	-	-

* Figures in parentheses refer to relevé numbers as shown in Table 2 of B-1 report on Mauna Loa Transect study.

PROGRESS OF INDIVIDUAL SUBPROJECTS

Publications

Our program has only been active for 1 1/2 years. Therefore, the first publications are only forthcoming now. We have decided that each publication originating from our group should be supplied with a contribution number. A footnote to the title should be cited uniformly as follows:

Contribution No. _____, ISLAND ECOSYSTEMS IRP/IBP HAWAII

The first five contribution numbers were the following:

#1 Howarth, F. G. In press. Cavernicoles in Lava Tubes on the Island of Hawaii. SCIENCE (1972).

#2 Mi, M. P., S. Yamashiro and D. Mueller-Dombois. In press. Data storage and retrieval for the study of Hawaiian ecosystems, Proc. Fifths Hawaii Intern. Confer. on Systems Sciences (1972).

#3 Gressitt, J. L. and C. J. Davis. In press. New plagithmysines from Kauai, Molokai and Hawaii. Proc. Hawaiian Ent. Soc. 21(1) (1971).

#4 Gressitt, J. L. and C. J. Davis. In press. Seasonal occurrence of the Hawaiian Cerambycidae (Col.). Proc. Hawaiian Ent. Soc. 21(2) (1972).

#5 Gressitt, J. L. In press. New plagithymysines from Molokai, Lanai and Maui. Pacific Insects 14(1) (1972).

Hawaiian Drosophila: a comparison of Kilauea and Olaa Forests - progress report

H.L. Carson

There are about 26 species of large endemic Drosophila ("picture-wings") known from the Big Island. The fauna of the Kilauea Reserve (virgin koa forest) is being compared with a section of the virgin Olaa Forest along Wright Road. The latter is under National Park protection but is not contiguous with the main park.

A team of 5-6 collectors is used. Each person establishes a central point and baits with 15-20 small (about 1cc each) dabs of a special banana bait around it. This is usually done for two successive days in the same location. All flies on or near the bait are individually collected by imprisoning under a vial. Sites near windfall trees are generally selected. Prior experience has shown that without such selection very few flies can be captured by this method. A simple effort-measure (flies per man-hour) has been calculated.

Table 1 gives the result of collecting in the two forests in April, June, September, and December of 1971.

Thirteen species (half the number for the entire island) are recorded at the Olaa Forest. Six of these species are also present in the Kilauea Forest. The predominant species at Kilauea (D. silvestris) is scarce in the Olaa Forest. The reverse is true for the predominant species in Olaa (D. setosimentum). Olaa is not only richer in species but populations appear to be more than twice as dense (7.8 flies per man-hour compared with 3.1 for Kilauea Forest). In the three collection periods, a total of 1082 picture-winged Hawaiian Drosophila have been captured so far. Collectors were: J. Aoki, G. and J. Ashton, H. and M. Carson, F. Clayton, E. Craddock, M. Delfinado, D. Hardy, W. Johnson, K. Kaneshiro, S. Malecha, R. Raikow and W. Steiner.

Table 2 shows the results from Kilauea Forest detailed as to specific sampling location in the 200 acre site.

Table 1. Species and numbers of individuals of picture-winged *Drosophila* captured in 1971 at two sites on Mauna Loa, Hawaii.

Species	Kilauea Forest 5300'					Olaa Forest 4000'				
	Apr	June	Sept	Dec	T	Apr	June	Sept	Dec	T
claytonae	0	0	0	0	0	0	3	3	0	6
digressa	0	0	0	0	0	4	5	31	14	54
hawaiiensis	0	1	0	1	2	0	0	1	0	1
heteroneura	0	0	0	0	0	1	1	3	7	12
macrothrix	0	0	0	0	0	1	7	21	3	32
murphyi	2	33	6	0	41	18	70	49	49	186
ochracea	0	0	0	0	0	2	4	2	0	8
paucipuncta	0	0	0	0	0	0	7	29	12	48
prolaticilia	0	0	0	0	0	1	3	1	2	7
setosifrons	0	4	1	0	5	5	25	6	4	40
setosimentum	0	0	1	1	2	52	17	131	90	290
silvestris	38	107	103	164	412	0	3	0	5	8
sproati	11	67	33	8	119	29	43	97	103	272
Totals	51	212	144	174	581	113	188	374	275	964
Man-hours collecting	32	57	42	32	163	29	32	26	25	112
Flies/man-hour	1.6	3.7	3.4	5.3	3.6	3.9	5.9	14.4	11.0	8.6

Table 2. Sampling points for 581 specimens of picture-winged Drosophila caught at Kilauea Forest in 1971.

	TRI, PLI				TRI, PL2				TRI, PL5		TR2,PL6
Species	Apr	Jun	Sep	Dec	Apr	Jun	Sep	Dec	Sep	Dec	Jun
hawaiiensis						1		1			
murphyi	1	7			1	18	5		1		8
setosifrons						1	1				3
setosimentum									1	1	
silvestris	34	41	33	50	4	24	59	68	11	46	42
sproati	10	18	6	1	1	33	26	2	1	5	16
Total	45	66	39	51	6	77	91	71	14	52	69
Man-hours	24	30	18	13	8	13	18	13	6	6	14
Flies/man-hour	1.9	2.2	2.2	3.9	0.8	5.9	5.0	5.8	2.6	8.6	4.9

Mauna Loa Transect study: Gradient analysis of vascular plant communities.

D. Mueller-Dombois
G. Spatz

The Mauna Loa Transect extends through a number of distinct structural and floristic ecosystems from tropical alpine to montane rain forest. In accordance with the plans of the Island Ecosystems Program outlined at the March and May 1971 workshop meetings, we intensified our vegetation sampling by establishing 81 new relevés along the altitudinal gradient from 4,000 to 10,000 feet.

Definitions

The relevés (= vegetation samples) were established in each 500 foot elevation interval, and they were defined as representatives of three life form communities. The three life form communities are:

(1) Tree community, defined as an aggregation of woody plants that form a "closed" canopy (meaning at least 60% ground cover) covering at least 60 m^2 ground surface (i.e., 2 or more trees) and that have their maximum crown biomass at 5 m height or taller.

(2) Shrub community, defined as a grouping of woody plants having their maximum crown biomass between .2-5 m height. Over 50% of the plant life forms in terms of shoot biomass must be shrubs (i.e., woody plants). No ground cover limit was assigned. Therefore, shrubs can be very scattered (e.g., 1 per $100m^2$), but they must always be more in quantity than herbaceous plants.

(3) Grass community, defined as a grouping of herbaceous plants among which more than 50% of the plant life forms must be grasses. No ground cover limit was assigned. Therefore, grass communities can also be very sparse or desert-like, but herbaceous life forms must predominate.

The three quantitative structural definitions match closely what most field biologists would intuitively classify as tree, shrub and grass communities, respectively.

Number and altitude of vegetation samples

The distribution of relevés by community-type is as follows:

Tree communities. We had 9 and added this summer 18 = 27 total.
Shrub communities. We had 4 and added 35 = 39 total.
Grass communities. We had 6 and added 28 = 34 total.

Therefore, we now have a total of 100 relevés analyzed between 4,000 and 10,500 feet elevation. Their distribution by ecosystem type is summarized in Table 1. For the purpose of site coordination, the altitude and number of each relevé is shown in Table 2.

Brief interpretation of Table 2

The tree communities are dominated by *Acacia koa* from 4,000 to 6,650 feet elevation, from 6,700 to 8,200 feet they are dominated by Metrosideros collina subsp. polymorpha var. typica. The shrub communities are dominated throughout their altitudinal range by Styphelia, from 4,600 - 6,600 feet by S. tameiameia, from 6,600 - 10,000 feet by S. douglasii. But there are other shrub species admixed. Major components in the grass communities are Paspalum dilatatum from 4,000 - 5,000 feet, then Holcus lanatus and Deschampsia australis become more important throughout the Mountain Parkland and up into the subalpine scrub forest, from 5,000 to 6,900 feet. From about 7,000 feet upwards, the few sparse grass communities are dominated by Trisetum glomeratum. The total quantitative species composition for each relevé will soon be available through computer retrieval.

Relevé size

The relevés were made large enough to include at least 90% of the species in each community, but they varied in size depending on the homogeneity of the cover and its density. Relevés in closed vegetation were usually 100 m^2 for grass cover and 200 m^2 for woody plant cover. In very sparse vegetation, such as found in the alpine ecosystems, relevé sizes were increased to 400 m^2.

The field record

In each relevé, all vascular plant species were listed in separate height strata as follows:

A1	$>$ 15 m	tall trees
A2	5-15 m	trees
B1	2-5 m	tall shrubs
B2	.2-2 m	shrubs
C1	$>$ .2 m	tall herbs
C2	$<$ .2 m	small herbs

The quantity of each species was estimated for its combined crown or shoot cover in each stratum by using the Domin-Krajina rating scale. This is a somewhat crude way of determining species quantities, but it is not superficial. The method does not take much time and is adequate for the purpose of gradient analysis. An example of a relevé record is shown as Table 3. The rating scale used for determining cover is given below the relevé record.

Computer storage and analysis

The 100 relevés are presently transferred to the computer for storage and subsequent analysis according to the objectives presented in the May 23, 1971 CIRCULAR LETTER to Hawaii IBP Participants.

Table 1. Summary of number of relevés by ecosystem type, Mauna Loa Transect, Segments 2 - 9.

Ecosystem type	Elevation range (feet)	Number of relevés* TC	SC	GC
Savanna	4000 - 5000	5	4	10
Mountain Parkland	5000 - 6650	10	9	15
Subalpine Scrub-forest	6650 - 7500	7	6	7
Treeline ecosystem	7500 - 8200	5	6	-
Alpine Scrub	8200 - 8500	-	2	-
Very sparse alpine scrub	8500 - 10,000	-	11	2
Moss desert	10,000 - 11,000	-	1	-
	TOTAL	27	39	34

* TC = Tree community
SC = Shrub community
GC = Grass community

Table 2. Altitude of relevés in three life form communities by ecosystem type and elevation interval.

Elevation interval	Ecosystem type	Altitude of relevés in feet TC*	SC	GC
		(relevé number in parentheses)		
#1	Savanna	4000 (62)	---	3950 (19)
4.00 - 4.49	(3900 - 5000')	4200 (39)	---	4000 (20)
		---	---	4000 (90)
		---	---	4100 (91)
		---	---	4400 (40)
#2	Savanna	4600 (96)	4600 (99)	4600 (97)
4.50 - 4.99		4700 (100)	4700 (101)	4600 (98)
		4900 (103)	4900 (89)	4700 (102)
		---	4960 (86)	4925 (85)
		---	---	4925 (88)
#3	Mountain	5000 (21)	5100 (23)	5100 (22)
5.00 - 5.49	Parkland	5350 (92)	5375 (94)	5200 (95)
	(5000 - 6650')	5440 (104)	5440 (106)	5350 (93)
		---	---	5430 (107)
		---	---	5440 (105)
#4	Mountain	5785 (83)	5680 (114)	5660 (112)
5.50 - 5.99	Parkland	5840 (108)	5790 (84)	5670 (113)
		5950 (115)	5820 (110)	5680 (111)
		---	---	5775 (82)
		---	---	5840 (109)
		---	---	5930 (116)
#5	Mountain	6200 (24)	6200 (25)	6100 (26A)
6.00 - 6.49	Parkland	6200 (117)	6200 (119)	6100 (26B)
		6400 (121)	6400 (122)	6250 (118)
		---	---	6400 (120)
#6	Subalpine	6650 (123)	6575 (81)	6575 (79)
6.50 - 6.99	Scrub-forest	6800 (17)	6620 (125)	6575 (80)
	(6650 - 7500')	6900 (77)	6625 (78)	6600 (124)
		6900 (129)	6850 (128)	6640 (126)
		---	---	6650 (127)
		---	---	6670 (135)
#7		7000 (16)	7100 (76)	6995 (143)
7.00 - 7.49		7100 (130)	7250 (131)	---
		7260 (132)	---	---
		7475 (75)	---	---
#8	Treeline	7500 (15)	7500 (74)	---
7.50 - 7.99	ecosystem	7650 (133)	7675 (73)	---
	(7500 - 8200')	7900 (72)	7680 (134)	---
		---	7950 (71)	---

Table 2 continued

Elevation interval	Ecosystem type	Altitude of relevés in feet TC* (relevé number in parentheses)	SC	GC
#9		8000 (11)	8000 (13)	---
8.00 - 8.49	Alpine	8000 (12)	8060 (136)	---
	Scrub	---	8250 (137)	---
	(8200 - 8500')	---	8400 (43)	---
#10	Very sparse	---	8600 (63)	---
8.50 - 8.99	Alpine Scrub	---	8900 (65)	---
	(8500 - 10,000')			
#11		---	9000 (138)	---
9.00 - 9.49		---	9200 (64)	---
		---	9325 (66)	---
		---	9500 (44)	---
#12		---	9625 (67)	9700 (141)
9.50 - 9.99		---	9650 (139)	9725 (68)
		---	9700 (140)	---
		---	9940 (70)	---
		---	9900 (142)	---
#13	Moss Desert	---	10,050 (69)	---
10.00 - 10.49	(10,000 - 11,000')			

* TC = Tree communities SC = Shrub communities GC = Grass communities

Table 3. Example of relevé record.

Information for each Hawaii Volcanoes National Park vegetation sample (=relevé). numbers 1-62

1. Date of field analysis
2. Relevé No.
3. Transect No.
4. Segment No.
5. Name of community
6. Location on 1 : 24,000 map
7. Altitude
8. Exposure
9. Slope
10. Substrate
11. Size of relevé
12. Remarks
13. Vegetation stratification

A	Tree layer	height	% cover
B	Shrub layer	height	% cover
C	Herb layer	height	% cover
D	Moss and lichen layer		
E	Epiphytes		

14. Species list and cover-abundance value (see last sheet)

Example Relevé No. 1

1. 15.8.66
2. 1
3. 3
4. 5
5. Open Metrosideros - native shrub - Andropogon community
6. Volcano; Hilina Pali Road
7. 3360 feet
8. S
9. 5%; almost level
10. ash on pahoehoe
11. 20 m (180°) x 25 m (270°) = 500 m^2
12. Tall grasses and shrubs abundant; 6 large Metrosideros snags in center of plot and several smaller ones present; many other Metrosideros snags outside the plot; pig scarification of Andropogon virginicus 3 x 5 m area.
13.

A 1	$>$ 10 m	40 %	45 %
A 2	3-10 m	5 %	
B 1	1-3 m	30 - 35%	50 - 65.%
B 2	.3 - 1 m	15 - 20 %	
B 3	$<$ .3 m	5 - 10 %	
C 1	$>$ 1 m	50 - 75 %	95 %
C 2	.3-1 m	20%	
C 3	$<$ .3 m	25 %	
D 1	On ground		
D 2	On litter		
D 3	On rocks		
D 4	On rotting wood		
E 1	On Metrosideros		
E 2	On Dodonaea		

E 3 On _Styphelia_

14. A 1

Metrosideros polymorpha var. _incana_ 7 trees

A 2

Metrosideros polymorpha var. _incana_ 7 trees

Santalum ellipticum var. _latifolium_ 1 outside

B 1

4 _Metrosideros polymorpha_ var. _incana_ 31 trees

3 _Dodonaea viscosa_ 8 shrubs

4 _Styphelia tamaiameia_

+ _Dubautia ciliolata_ 6 shrubs

B 2

2 _Wikstroemia phillyreaefolia_ 8 plants

4 _Styphelia tamaiameia_

4 _Dodonaea viscosa_

2 _Dubautia ciliolata_

1 _Metrosideros polymorpha_ var. _incana_

1 _Vaccinium reticulatum_

B 3

2 _Dodonaea viscosa_

1 _Styphelia tamaiameia_

3 _Vaccinium reticulatum_

4 _Coprosma ernodeoides_

2 _Dubautia ciliolata_

C 1

2 _Rhynchelytrum repens_

4 _Machaerina angustifolia_

2 _Andropogon glomeratus_

8 _Andropogon virginicus_

C 2

1 Fimbristylis dichotona

2 Andropogon glomeratus

2 Rhynchelytrum repens

2 Setaria geniculata

+ Briza minor

1 Youngia japonica

2 Sporobolus africanus

+ Erigeron canadensis

3 Luzula hawaiiensis

4 Polypodium pellucidum

2 Sonchus oleraceus

+ Gahnia gahnifolia

+ Eupatorium riparium

4 Agrostis avenaceae (retrofracta)

(+) Cyperus hillebrandii

3 Andropogon virginicus

2 Digitaria violescens

2 Emilia javanica

3 Dianella lavarum

2 Cyperus polystachyos

2 Gnaphalium purpureum

C 3

1 Hypochaeris radicata

4 Carex wahuensis

2 Youngia japonica

3 Elaphoglossum reticulatum

4 Andropogon virginicus

2 *Bulbostylis capillaris*

2 *Digitaria violescens*

1 *Psilotum nudum*

2 *Cyperus polystachyos*

3 *Agrostis avenacea (retrofracta)*

2 *Fragaria vesca*

1 *Gnaphalium purpureum*

1 *Vulpia megalura*

3 *Polypodium pellucidum*

3 *Cyperus brevifolius*

2 *Sacciolepis indica*

2 *Briza minor*

+ *Pleopeltis thumbergiana*

2 *Rhynchelytrum repens*

4 *Gahnia gahniaeformis*

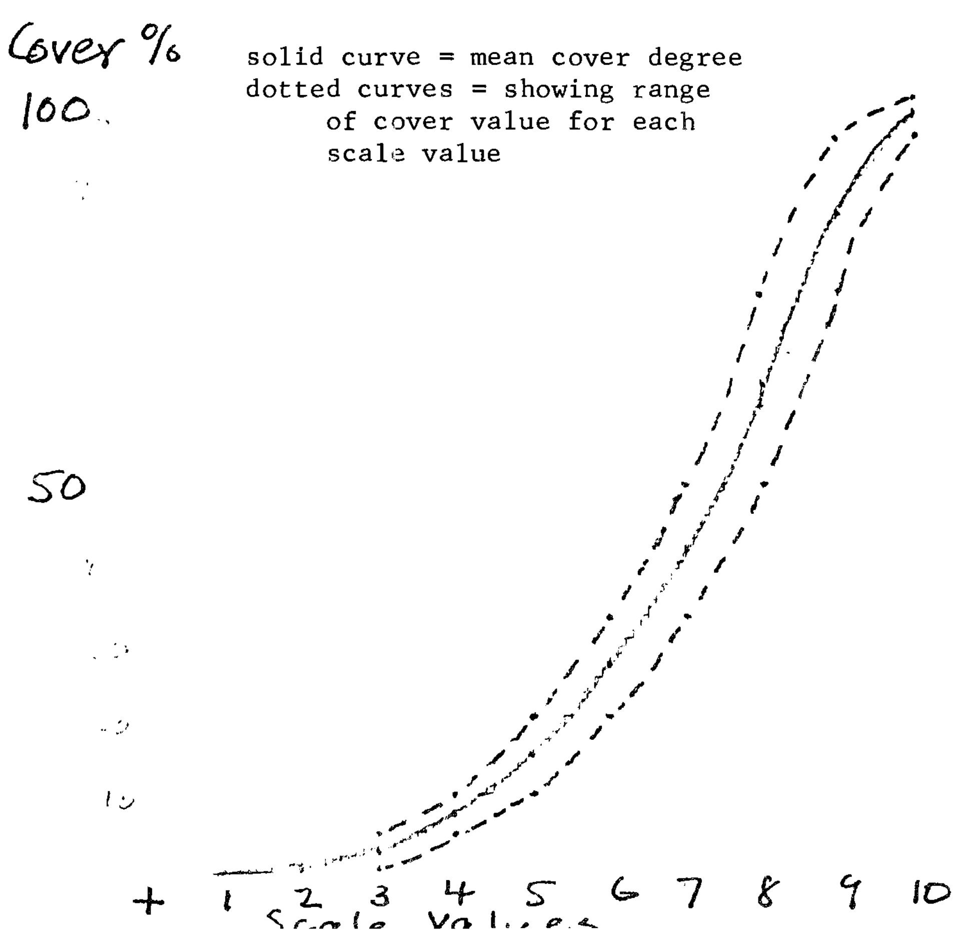
+ *Spathoglottis plicata*

3 *Conyza canadensis*

Meaning of modified Domin-Krajina cover-abundance estimate scale (Mueller-Dombois 1964, Canadian J. Botany 42: 1421)

Rating Code	Meaning	Cover % Range	Mean Cover degree
10	any number, with complete cover	95 - 100	97.5 %
9	any number, with more than 3/4 but less than complete cover	75 - 95	85.0 %
8	any number, with 1/2-3/4 cover	50 - 75	52.5 %
7	any number, with 1/3-1/2 cover	33 - 50	41.5 %
6	any number, with 1/5-1/3 cover	20 - 33	26.5 %
5	any number, with 1/10-1/5 cover	10 - 20	15.0 %
4	any number, with 1/20-1/10 cover	5 - 10	7.5 %
3	scattered, with cover under 1/20	1 - 5	3.0 %
2	very scattered, with small cover	<1	.5 %
1	seldom, with small cover	very small	.1 %
+	solitary, with small cover		ignore

Curve showing relation of mean cover degree (%) to Domin-Krajina cover-abundance estimate scale



Study on the influence of introduced large herbivores on the vegetation in Hawaii Volcanoes National Park

D. Mueller-Dombois
G. Spatz

Previous observations (Mueller-Dombois 1967) have shown that an important factor overriding the direct correlation of physical environment with vegetation are the introduced large herbivores. They include in the IBP study sites cattle, goats and pigs. Pigs were found to be of particular importance in the Kilauea rain forest, and part of the future plant ecological studies will be devoted to the impact of pigs on the rain forest vegetation. Cattle was present in the mountain parkland and savanna ecosystems of the National Park until they were removed in 1948. The Park boundary fence goes parallel to the Mauna Loa Transect and cattle ranching continues outside this fence in these two ecosystems. A study of cattle influence will form a separate study.

Following a vegetation mapping project in the National Park (Mueller-Dombois 1966) the principal investigator suggested to the Park authorities construction of several exclosures against goats and pigs in different ecosystems along the transects. In 1968 the Park Service erected a 100 x 10 m goat exclosure in the mountain parkland ecosystem along the Mauna Loa Transect at 6200 feet elevation. A 60 x 10 m pig exclosure was erected in the ohia-tree fern forest near Thurston Lava Tube (segment 12 , Transect 1). A second goat exclosure was established in the perennial _Andropogon_ grassland ecosystem above Hilina Pali and another one in the annual _Eragrostis tenella_ grassland below Hilina Pali. Their positions are in ecosystems along Transect 2 (segments 4 and 2 respectively) in seasonally dry climates.

In connection with the ecosystem transect studies inside Hawaii Volcanoes National Park, we devoted part of our vegetation-environment correlation studies to the influence of goats.

The following reports relate to studies of the two goat exclosures in the mountain parkland and in the annual grassland.

(a) Influence of goats on koa reproduction in mountain parkland ecosystem, Mauna Loa Transect.

Goats (like cattle) are a relatively recent addition to the biota on the Hawaiian Islands. They were brought to Hawaii with the first explorations of the white man, about 200 years ago. Since then, they have multiplied and spread into all natural vegetations in climates with dry seasons. Here they found no natural predators, except man. Their population numbers are therefore controlled only by availability of food, by their own capacity to reproduce and by interference from man.

Their food supply consists of nearly all plants available in the dry-zone habitats, but as is well known, their preference is for woody species. Foremost among them is one of the two most important native tree species, _Acacia koa_ (koa).

Acacia koa occurs on all high Hawaiian Islands, usually in locally restricted areas bordering the Metrosideros (ohia) rain forests. Acacia koa can be found forming closed forests, but often occurs more or less scatttered in grass-covered areas. Where open-grown, its distribution may have been influenced by fire and grazing (Mueller-Dombois and Lamoureux 1967).

On the east-flank of Mauna Loa, Acacia koa is prevalent between 4,000 - 6,600 feet elevation. Here, it occurs in small forest stands that are haphazardly distributed within a matrix of grass and scrub vegetation. This type of vegetation is locally referred to as mountain parkland, and a sizable portion of this occurs within the boundaries of Hawaii Volcanoes National Park.

In this ecosystem, Acacia koa reproduces almost entirely from root suckers (Mueller-Dombois 1967), while in the Kilauea rain forest, koa reproduction is primarily from seed. The sucker reproduction of koa in the mountain parkland ecosystem is responsible for the occurrence of koa in circular colonies in this habitat. One or two old trees are often found in the center of these colonies and the outward growth is characterized by concentric rings or belts of successively smaller koa suckers. Part of this study was also devoted to the question of what stimulates the sucker reproduction of koa in this habitat. This question is partially answered by the goat impact study on koa.

So far, no quantitative information on the impact of goats in Hawaii has ever been published. The information given here is incomplete and only for the purpose of indicating the progress of this study.

The methods employed relate to quantitative analyses of the Mauna Loa Strip Road exclosure (6,200 feet), its surrounding vegetation and to the structural analyses of several koa tree communities in the mountain parkland ecosystem.

Exclosure transects

Ten transects were established across the exclosures (Fig. 1). Along the 10 transects all koa suckers were counted in two meter broad strips and their heights were measured. Additionally, their positions were mapped. The percent shoot cover of each species was estimated for every meter along the strips. The cover for herbs and grasses, shrubs, trees and the total cover were also established. The total sample includes about 100 m^2 inside and 50 m^2 outside the fence.

Transects through unfenced koa colonies

In addition to the exclosure analysis, 5 other transects between 30-50 m long were established through two unfenced typical koa colonies at 1,650 m (5,400 feet) elevation. Along these transects all koa trees in a 2 m broad strip were measured and counted. Each tree recorded was classified as either undamaged, browsed, broken or girdled by goats. The measured koa individuals were subsequently grouped into 10 height classes for each belt-transect.

Results of exclosure study

Table 1 shows the result of the koa sucker enumeration in the 10 belt-transects of Fig. 1. Sucker density is given in number of individuals per square meter for each of 9 height classes for inside and outside the exclosure. The average number of koa suckers is shown at the bottom of Table 1.

From these values it can be seen that the number of suckers below 5 cm height is much greater outside the exclosure than inside. Suckers between 5-10 m tall are about equal in number outside and inside. The number of suckers above 10 cm decreases outside, and suckers from 0.5 m to 5 m height are completely absent outside. Suckers between 5 - 10 m height are again equal in number inside and outside the exclosure.

Interpretations

These tall (5-10 m) suckers obviously were there before the exclosure was built in 1968, and they are unaffected by the fencing. The smaller suckers from above 2 m height downwards in size show the effect of protection from goat browsing, which is manifested by the much greater number of suckers from 10 cm to above 2 m height found inside the exclosure.

The 1-2 m tall suckers are probably 3 years old indicating a mean height growth of koa suckers of about 50 cm per year when not browsed. When severely browsed, suckers never reach this height, and as shown by the very large number of small suckers (below 5 cm height), they remain cropped close to the ground. This situation may allow grasses to overgrow such places and goats, if maintained constantly in high populations, can thus totally eliminate koa trees from the mountain parkland by interfering with their reproduction cycle.

The results of the structural analyses of unfenced koa colonies permit recognition of the local intensity of goat impact on koa in this ecosystem. Additional transects are being run and the data is currently assembled for publication.

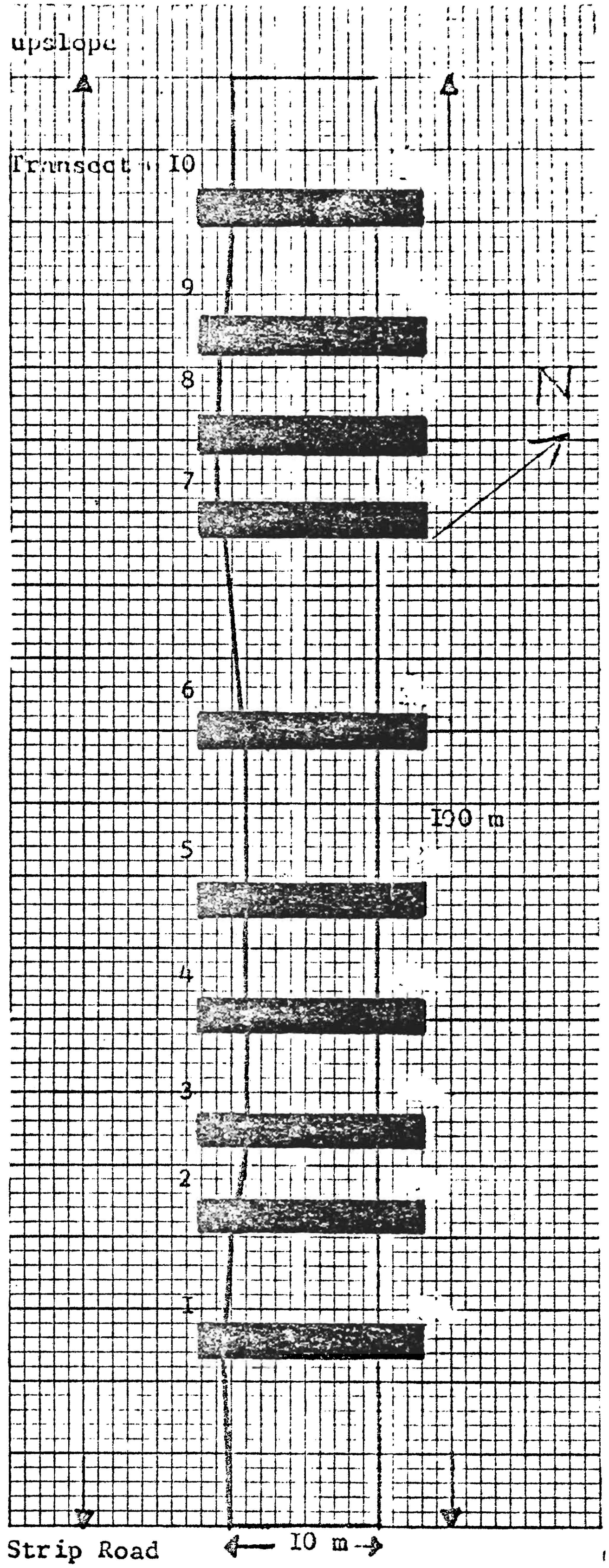


Fig. 1: Goat exclosure at 1,890 m
(6,200 ft.) elevation

Table 1. Number of koa suckers per square meter inside and outside the Mauna Loa Strip Road goat exclosure, June 1971.

Height class	1		2		3		4		5		6		7		8		9	
Range in cm	< 2		2.1 - 5		5 - 10		10 - 25		25 - 50		50 - 100		100 - 200		200 - 500		500 - 1000	
Fenced	in	out	in	out	in	out	in	out	in	out	in	out	in	out	in	out	in	out
Transect # 1	-	1.32	-	0.09	0.11	-	0.27	-	0.05	-	-	-	-	-	-	-	-	-
2	0.26	3.27	0.74	1.27	1.21	0.91	0.95	-	1.11	-	0.42	-	0.21	-	-	-	-	-
3	-	0.83	1.17	0.08	0.78	0.08	1.11	-	1.55	-	1.11	-	0.11	-	-	-	-	0.17
4	-	1.50	-	0.25	-	0.25	0.11	0.08	0.17	-	-	-	-	-	-	-	0.33	-
5	-	2.67	0.05	2.15	-	0.34	0.22	-	0.49	-	0.43	-	0.05	-	-	-	0.11	-
6	0.22	2.42	0.11	0.75	0.72	0.08	2.00	0.08	2.00	-	0.83	-	0.05	-	-	-	-	0.08
7	-	6.02	-	6.70	0.33	2.27	1.98	0.68	5.42	0.57	4.71	-	2.69	-	-	-	-	-
8	-	2.63	0.09	2.00	0.55	0.63	1.14	0.50	2.45	-	2.23	-	0.23	-	-	-	-	0.13
9	0.05	5.54	0.28	4.52	0.61	0.68	1.14	-	1.84	-	1.51	-	0.38	-	0.19	-	-	-
10	0.20	2.10	0.05	1.80	0.65	0.80	1.15	-	1.60	-	1.60	-	0.15	-	0.05	-	0.15	-
average 1 - 10	0.07	2.83	0.25	1.96	0.50	0.61	1.03	0.14	1.67	0.06	1.29	-	0.40	-	0.02	-	0.06	0.04

(b) Influence of goats on annual grass community, Hilina Pali lowland

The lowland exclosure, known as Kukalauula Exclosure, is in an area covered dominantly by an introduced annual grass, Eragrostis tenella. Woody plants are virtually absent from this ecosystem, although the rainfall is high enough (about 500-750 mm) to support woody life forms. The substrate is formed by a shallow layer of ash over broken and strongly fissured pahoehoe lava. The location of the exclosure is at 1000 feet elevation of Kukalauula Pali. Its size is 100 x 7 m. It was constructed in August 1969.

Method of analysis

In July 1971, two years after construction, the exclosure was analyzed by the point frequency method for species cover. Four transects were run as shown on Fig. 2. The transects were 20 m long and run across the exclosure to include inside and outside information. The sample points were 20 cm apart. Five points were sampled per meter with a point frequency frame. The total sample was 270 points outside and 140 points inside (of which 16 points were in the grazed inner fringe). Our field work was assisted by D. W. Reeser, Park Ranger.

Results

The percent cover for all plant species is shown in Table 2. The data are separated for outside and inside the exclosure and for the grazed inside fringe.

Table 2. Percent cover of plant species inside and outside the Kukalauula Exclosure, July 1971.

Species	inside	grazed inner fringe	outside
Cynodon dactylon	30.6	37.5	30.7
Eragrostis tenella	5.7	37.5	30.7
Desmodium triflorum	8.6	12.5	7.4
Euphorbia hirta	-	-	3.0
Cyperus brevifolius	-	-	1.5
Chrysopogon aciculatus	-	-	1.5
Phyllanthus niruri	-	-	1.1
Bulbostylis capillaris	-	-	0.4
Sporobolus africanus	4.8	-	-
Cassia leschenaultiana	1.6	-	-
Rhynchelytrum repens	0.8	-	-
Waltheria indica	+	-	-
Erigeron sp. (dead)	+	-	-
Indigofera suffruticosa	+	-	-
*Canavalia sp.	51.6		
*Sisyrynchium acre	+	-	-
*Heteropogon contortus	+	-	-
barren soil or litter	-	12.5	18.0
barren rock	0.8	-	5.9
goat pellet	-	-	0.4

* native plants, the others are all exotics. + mean less than 1 percent.

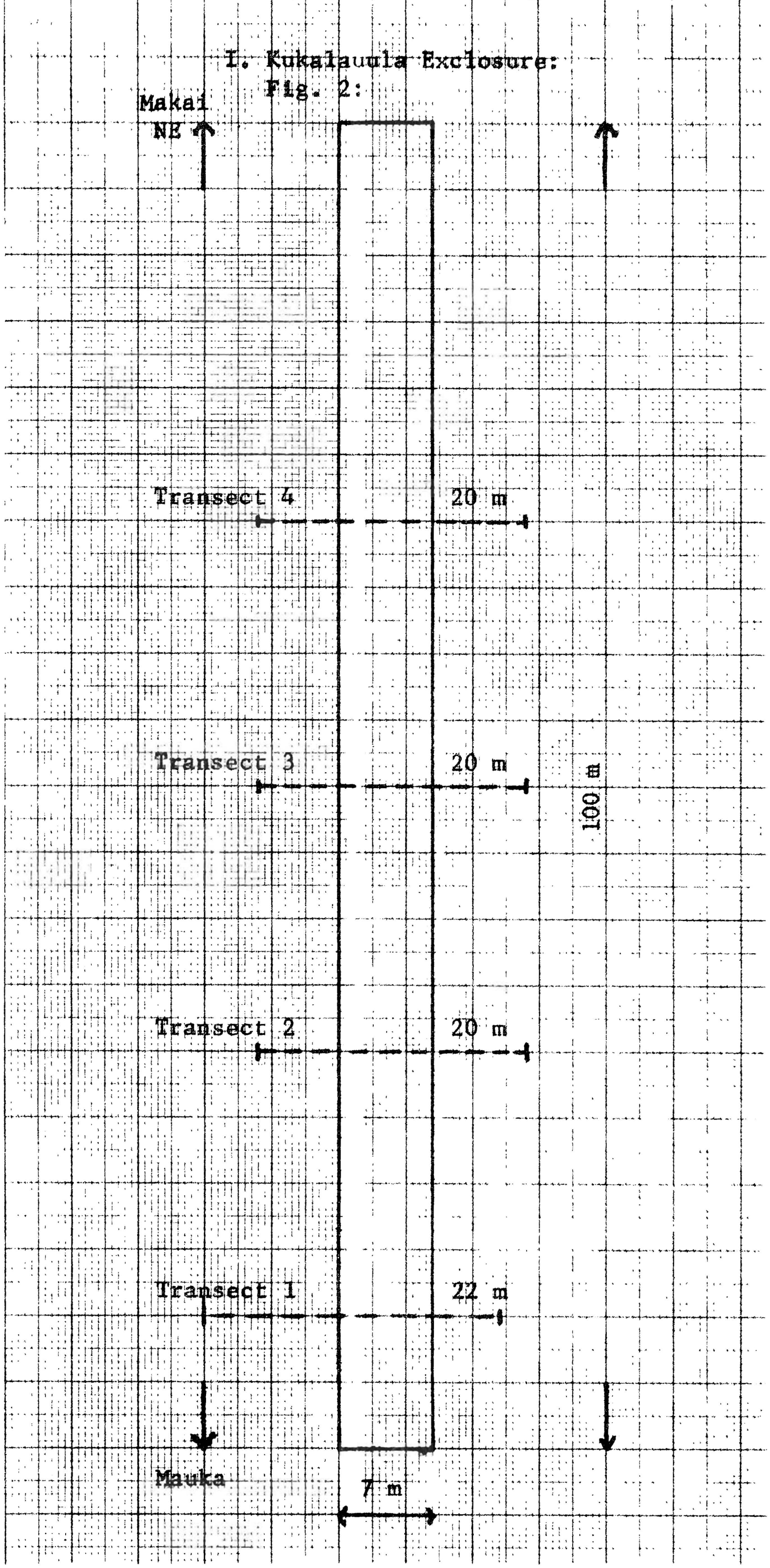


Fig. 2   Kukalauula Exclosure and sample transects.

Interpretation

The most striking response to the absence of goat feeding was the presence of a herbaceous legume vine, Canavalia sp. This plant covered more than 50 percent of the ground surface in the exclosure. From a distance, the vine made the exclosure stand out like a green island in the midst of the dried-up yellow grassland. The Canavalia sp. grew with great vigor (almost as if irrigated) to an approximate height of 30 cm. This plant is found nowhere else in the Hilina Pali lowland, and its taxonomic status is currently investigated by Dr. Harold St. John. It will be described as a new endemic species.

Another interesting response was the presence of three woody plants (Cassia leschenaultiana, Waltheria indica, Indigofera suffruticosa) inside the exclosure, while none were seen outside.

Moreover, three bunch grasses were found only in the exclosure, Heteropogon contortus, Sporobolus africanus and Rhynchelytrum repens. The cover of the annual grass Eragrostis tenella had decreased significantly from 31% to 6%, obviously, as a result of competition of the newly invaded perennial plants. A few weedy species, which were present outside the exclosure, did not appear in the inside sample. These were two annuals (Bulbostylis capillaris, Phyllanthus niruri), a stoloniferous grass (Chrysopogon aciculatus) and a low-growing weed (Euphorbia hirta). The latter was found only where the grass cover had locally disappeared from overgrazing and trampling. The exposure of barren soil and litter was 18% outside, while inside the soil was totally overgrown by vegetation. Two perennial herbs (Cynodon dactylon, Desmodium triflorum) showed the same cover inside and outside. However, both species responded inside by growing up to 20 cm tall, while they were closely cropped and lower than 5 cm outside.

Conclusions

The result of this exclosure experiment shows clearly the very strong influence of goats on shaping the vegetation in this lowland habitat. But, the results refer only to the first stage of a succession. It is remarkable that already three native species are participating in this early recovery process (Canavalia sp., Heteropogon contortus and Sisyrynchium acre). It can be expected that the cover by woody plants will increase in the near future and that the annual and stoloniferous herbaceous life forms will soon disappear totally.

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Kilauea rain forest study

D. Mueller-Dombois
R.G. Cooray
Jean Craine

The comprehensive plant ecological survey of the 200 acre IBP study site in the Kilauea Forest Reserve has been completed. The field work was done by two graduate students, Ranjit G. Cooray and Jean Craine, who are presently assembling their data for analysis and interpretation to be used in each case for a M.Sc. thesis. Ranjit Cooray is working on a structural analysis of all woody plant species in this rain forest and Jean Craine on a pattern analysis of the undergrowth communities. These studies will form a contribution to the question of stability in a dominantly native Hawaiian rain forest ecosystem.

The field procedure followed was essentially that outlined in Technical Report #1, pages 56-77. However, a few modifications were introduced. First of all, the complete survey was done only along transects 1 (sample plots 1-5) and 4 (sample plots 16-20) (see Fig. 1, p. 59 of Tech. Rpt. #1). After completing these two outer transects with their total of 10 plots, and after walking and outlining the inner two transects, it was felt that the essential variation in the 200 acre site was already included. Therefore, the two central transects were omitted from further complete field analysis. Analysis of the data will show whether this assumption was valid. Nevertheless, all trees taller than 5 m were counted along all four transects.

Other departures from the original outline include the following:

1. In addition to counting in subsamples, the seedlings of all potential trees in the forest, all woody plant seedlings (i.e., also the seedlings of shrub species) were sampled for density.

2. The sampling base per plot was enlarged by sampling sixteen 5 x 3 m subplots instead of only ten for all plant categories (except bryophytes, which were assessed only in the first four 5 x 3 m subplots).

3. Instead of using as originally planned a minimum number of 100 individuals for enumeration of different size classes, the enumeration was based on an area-sample: All trees and shrubs (inclusive of seedlings) were counted by size and species along a 6 m wide strip to a distance of 100 m from each plot point. All woody plants taller than 5 m were counted (by size classes) in continuous 1000 m long belt-transects for all four transects.

4. In addition to the original plan, cover for two height strata (.5 - 2 m and 2.1 - 5 m) was established by the line-intercept method along the two 1000 m transects.

Both students presented a progress paper at the October 8 annual meeting of the Island Ecosystems IRP. The essence of their presentations is given in the following reports.

R.G. Cooray
D. Mueller-Dombois

(a) Tree population structure and dynamics

Following field reconnaissance and establishment of a sampling procedure for the Kilauea rain forest in September 1970, transects 1 and 2 were flagged out in January 1971, and transects 3 and 4 in June. The comprehensive plant ecological survey was begun in April 1971 and completed during June and July.

Field method

All woody plant species were sampled in various size classes from seedling to mature stage. Among seedlings, two classes were recognized: (1) germinants (<10cm tall seedlings), (2) established seedlings (seedlings from .1 - .5 m tall). From .5 m height on, woody plants were counted in five stem-length classes up to 5 m height. Above 5 m height, woody plants were enumerated by diameter at breast height.

To obtain an adequate number in each size class, the following area-samples were taken along the transects. Along transects 1 and 4, seedlings were enumerated in 40 x 6 m belt-transects starting 145°SE from each of the five plot points (see Fig. 1; TR1 plot points 1-5; TR4 plot points 16-20). Woody plants up to 5 m stem length were enumerated over 100 x 6 m belt-transects at the same 10 plot points. Woody plants over 5 m height were enumerated along all 4 transects in continuous belt-transects, each 1000 x 6 m. In addition, trees over 13 inches in diameter at breast height (which were the emergents, mostly Acacia koa and a few Metrosideros collina subsp. polymorpha) were measured by the point-centered quarter method. This was done at each of the 10 plot points and at the 50 and 100 m points in SE direction of each plot point. Thus, a total of 120 over 13-inch trees were enumerated by this method.

Some preliminary results

The Kilauea Forest shows a relatively low diversity of woody plant species when compared with montane rain forests in other parts of the world. Only 17 woody plant species were found in the study site.

These could be grouped into 3 abundance classes. Acacia koa and Metrosideros collina are the most common tree species and are found throughout the forest. The second abundance class includes Cheirodendron trigynum, Ilex anomala and Pelea spp. which are found scattered throughout the forest. The third group are rare species. Of these, less than 5 individuals per species were enumerated in the entire sample. The rate group includes species such as Clermontia hawaiiensis, Myrsine sandwicensis, and Pipturus hawaiiensis, among others.

Among the common species, Metrosideros collina subsp. polymorpha shows abundant regeneration by seedlings. The seedlings were mostly found on rotting logs, but a few seedlings were observed also on mineral soil. All size classes from germinants to emergent trees were recorded for this tree species. Metrosideros density decreased from 200-270 seedlings per 100 m^2 to 26-27 individuals per 100 m^2 of trees 5 m and taller.

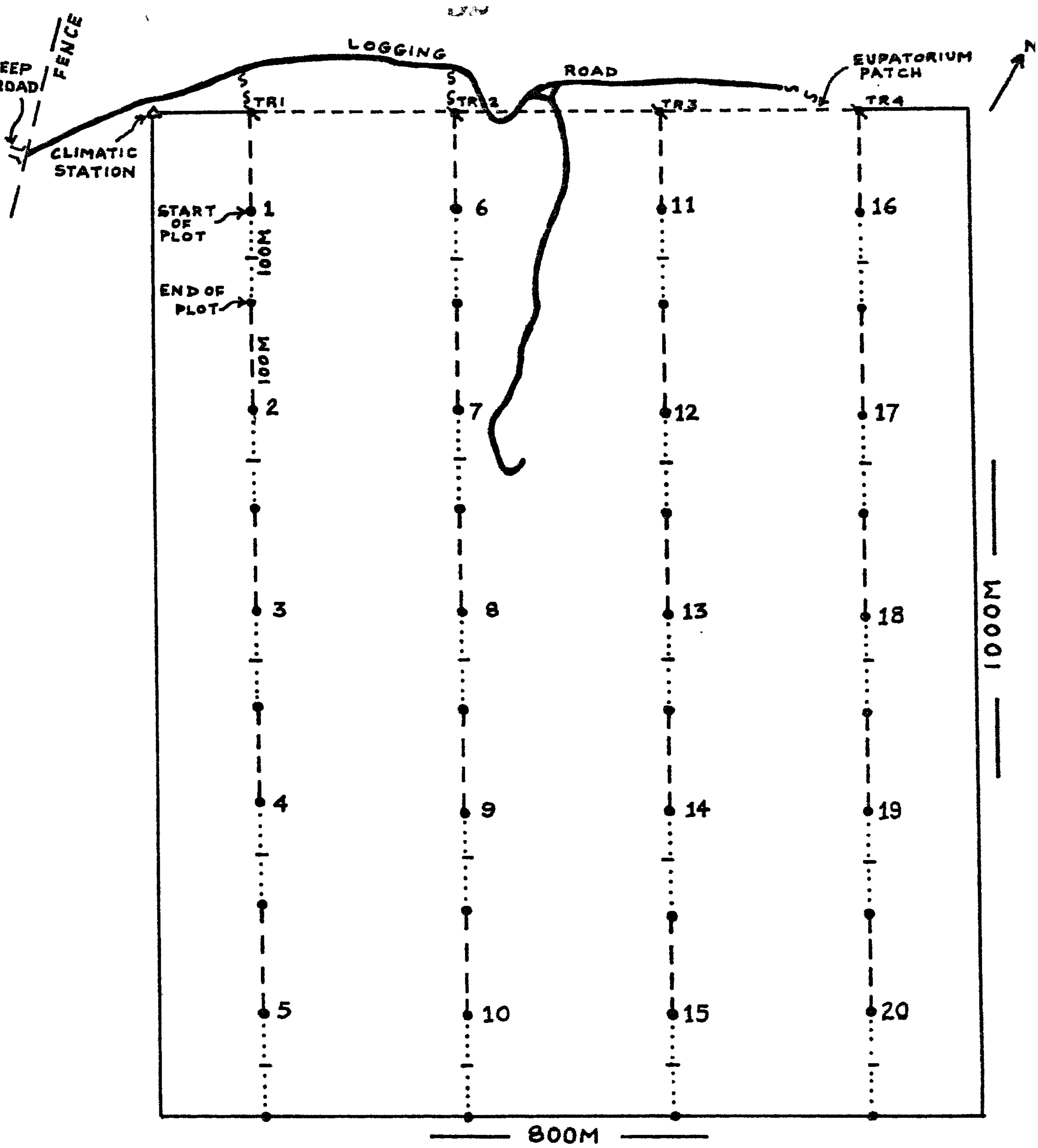

Fig. 1. Kilauea Forest Reserve IBP study site orientation map for participants.

outline of study site.
--------- base line (55°NE) white flags every 5 meters.
blue flags every 5 m from base line to start of plots 1,6,11 & 16 and between plots on transects. (145°SE)
orange flags every 5 m in plots on transects. (145°SE)
blue flags from logging road to base line.
starting points of transects marked with tag & blue & white flags
starting & end points of plots marked with tag, blue & orange fla
50 m point in plots marked with tag, blue & orange flag.

Acacia koa reproduces by two methods, from root suckers arising from injured exposed roots and from seedlings. The root suckers are localized in places where roots are exposed. Small seedlings, often with cotyledons still intact, were common on mineral soil and rotting logs. But, seedlings of koa were much fewer than seedlings of *Metrosideros*. Koa had a very unequal size distribution . Rare were intermediate sizes, more common were seedlings and emergents. The few intermediate sized koas were found growing on root collars of fallen koa trees. Many fallen koa trees were present, but not all had koa regeneration on the root collar. The less abundant tree species, *Cheirodendron trigynum*, *Ilex anomala* and *Pelea* spp. show good regeneration. Seedlings of these and *Coprosma rhynchocarpa* were common. Most of the seedlings were found on rotting logs. Little or no regeneration was observed for the rare woody species. Their maintenance and distribution in this forest pose an interesting question that should also be studied.

The reproduction pattern of *Acacia koa*

However, one of the initial objectives of this study is to determine the place of koa in this forest ecosystem. The replacement pattern of koa seedlings and saplings on the elevated root collars of fallen koa trees was slightly less than 1 : 1. This means that somewhat less than 100% of the root collar positions were occupied by koa regeneration. Seedlings and root suckers of koa were found on mineral soil, but few were seen to attain a height of over 2 m. These few were found in protected positions, in areas fenced off naturally by large fallen tree trunks. Thus, the primary niche of the koa saplings was on root overturns. It is possible that these root collar positions are more favorable than the forest floor for koa survival because the immature plants receive more light here. This possibility will be checked. However, profile diagrams of several forest sections along the transects indicate that large openings are available on the forest floor. Much sunlight reaches the forest floor in these openings, but, in spite of this, intermediate sized koa trees were absent. The degree of shade tolerance of *Acacia koa* is not yet known, but the root collar positions and forest floor areas do not seem to differ significantly in light availability.

The possible role of pigs

Several instances of chewed koa root sprouts were observed during the survey. The sprouts were chewed at a height of less than 10 cm from the ground. Only the leaves were stripped and the stems showed dried-up mud at the clipped ends. This observation provided circumstantial evidence that pigs feed on koa seedlings. Pig feeding of koa seedlings would also explain why saplings can survive on elevated root collars and in otherwise protected positions.

Abundant pig activity was observed on the forest floor. Soil scarification, feeding marks on tree fern trunks, and feces were commonly noted. Many live pigs were seen during the field work.

These observations lead to the hypothesis that the pig is a major factor in the dynamics of this forest ecosystem. Among other influences, the pig seems to interfere with the current reproduction cycle of koa. The effects of rats and mice on koa reproduction in the Kilauea forest are not yet known. It is possible that these rodents feed on koa seed and also on young seedlings. Dr. Tomich's studies (D-2) may contribute knowledge on the effects of these rodents on koa reproduction. Pigs seem to affect the koa reproductive cycle at a later stage by chewing of foliage from seedlings. Their trampling, ploughing and wallowing could also uproot young seedlings.

Pig exclosures and pig activity

As a result of these observations, several small pig exclosures were recently established in the 200 acre IBP site. Some exclosures were built around existing root suckers, others were supplied with koa seeds. Additional exclosures are planned to thoroughly study the effects of pigs on this rain forest vegetation. A pig activity survey was made along the 4 transects that included information on feces, freshly scarified areas, feeding on tree fern trunks and koa seedlings in a semi-quantitative manner. These results are being analyzed.

Tree structure analysis

The woody plant data is being analyzed in the form of number/size class curves to determine more clearly the current natural replacement pattern of the more abundant woody species in this forest.

Jean Craine
D. Mueller-Dombois

(b) Spatial pattern of plant synusiae

This study is concerned with the mathematical detection of undergrowth community patterns in the Kilauea rain forest.

The term "synusia" is used to more closely specify the kinds of undergrowth communities that will be analyzed for pattern. A synusia is commonly defined as a layer community. In a typical forest, one can often recognize at least four synusiae or layer communities, one each formed by the trees, the shrubs, the herbs and the mosses on the ground. These four synusiae can often be further subdivided on the basis of life form similarity of the species growing in each layer. Thus, in a narrower sense, synusiae can be defined as subcommunities that are comprised of species of similar life form growing together in the same ecosystem.

It was thought that this study would be of interest because the overall impression of the 200 acre IBP study site and the surrounding (at least 1000 acre) rain forest ecosystem appears extremely homogeneous on the 1 : 12,000 air photo. This homogeneity is caused primarily by the more or less random distribution of the scattered emergent Acacia koa (koa) trees. Underneath the koa trees, the vegetation appears to be less homogeneous. In certain places, Metrosideros collina subsp. polymorpha (ohia) subcanopy trees appear to be aggregated, in others more widely scattered. Similarly, tree ferns (Cibotium spp.) are not uniformly distributed throughout the forest, even though, on first view, they appear to be.

A few obvious patterns are found in the forest. For example, there are a few wet and boggy depressions that are stocked with Carex species while tree ferns are absent, also there are canopy gaps where old big koa trees have fallen.

The purpose of this study is to find out whether these more obvious and less obvious variations can be detected mathematically through an objective field sampling technique. Moreover, when such patterns are demonstrated, the study will serve as the basis for further research into the causes and stability of these variations.

Field procedure

The field survey was done together with Ranjit Cooray, who will use the density by size class data of woody species for the tree population structure analysis. The data set for the spatial pattern analysis was obtained for the following synusiae (see Procedure for Sampling the koa ohia-tree fern forest, pp. 56-77 in Tech. Rpt. #1):

1. Moss and liverwort synusia on forest floor, which is restricted to decaying wood and lying logs

2. Epiphyte synusia (only vascular plants)

3. Herbaceous plant synusia, including woody plants up to .5 m tall. The latter may later be subdivided as a special synusia.

4. Shrub synusia, including all woody plants from .5 - 5 m stem length;

(Stem length rather than height was used because in this forest stems are often leaning, bent or in the case of the tree ferns, trailing on the ground or over logs).

5. Subcanopy tree synusia, including all trees from 5.1 m stem length upwards to a diameter at breast height (dbh) limit of 32.5 cm (13 inches).

6. Canopy and emergent trees, including all trees from 32.6 cm (13.1 inches) dbh upwards. The emergent tree or canopy synusia will also be analyzed for its influence on the undergrowth synusia.

The main parameter recorded for this analysis was vertical crown or shoot cover. The cover of the moss and herb synusiae was estimated for each species separately in 5 x 3 m subplots. The cover of the shrub synusia was obtained by the line-intercept method. The crown cover of the subcanopy tree synusia was approximated by measuring a large number of dbh/crown diameter relationships, and by extrapolating to crown cover from the diameter records. The cover of the emergent koa trees will be obtained from a large-scale air photo by use of a dot-grid.

The basic area-sample was a 40 m long belt-transect of 6 m width that was subdivided into sixteen 5 x 3 m subplots. These belt-transects began at each plot point located on the two outer transects (TR 1 and 4) in the IBP study site. Ten such belt-transects or plots were surveyed for each, the herb, shrub, subcanopy and emergent tree and vascular epiphyte synusiae. The moss synusia was surveyed only in four 5 x 3 m subplots in each of the 10 plots. Since the quantity of plants per area decreases with the size of plants, additional area-samples were taken for the woody plant synusiae. The shrub synusia was surveyed over a 100 m long belt-transect and the subcanopy and emergent tree synusiae over a 200 m long belt-transect starting at each of the 20 plot points along the 4 transects. To further supplement the sample of the scattered emergent trees, they were sampled additionally by the point-centered quarter method. Three sampling points were used for each of the 10 plots, at the starting point, at the 50 m point and at the 100 m point. Thus, the point-quarter sample included 120 emergent trees. Since density data was taken for all woody plants, the latter may also be subjected to spatial variation analysis .

Computer analysis

Presently, all field data is being transferred onto computer cards. At least two methods are contemplated for data analysis, the pattern analysis method of Greig-Smith (1961 J. Ecol. 49:695) and the Wisconsin ordination method (Bray and Curtis 1957 Ecol. Monogr. 27:325 and Newsome and Dix 1968 Am. Midl. Natural 80:118).

(c) Provisional Checklist of Plants from IBP Study Site Kilauea Forest Reserve, Hawaii, 5,400 feet elevation.

(Compiled by Ranjit G. Cooray)

Algae

Chlorophyceae
- Nitella sp.
- Spirogyra sp.

Cyanophyceae
- Anacystis dimidiata (Kuetz.) Drouet & Daily
- Palmogloea protruberans (Sm & Sw.) Kuetzing
- Schizothrix tenerrima (Gomont) Drouet

Fungi

Phycomycetes
- Pilobolus sp.
- Piptocephalis sp.

Lichens

- Cladonia sp.
- Stereocaulon sp.

Bryophytes

Hepaticae
- Anastrophyllum fissum
- Bazzania cordistipula
- Bazzania sp.
- Calypogeia torana
- Calypogeia sp.
- Dumortiera hirsuta
- Lepidozia australis
- Lophocolea sp.
- Odandochisma sandvicense
- Pallavicinia sp.
- Symphyogyna sp.

Musci
- Campylopus sp.
- Hypnum sp.
- Leucobryum gracile Sull.
- Plagiothecium draytonii
- Pogonatum sp.
- Rhizogonium spiniforme
- Thuidium sp.

Anthocerete
- Anthoceros sp.

Pteridophytes

Dicksoniaceae

Cibotium chamissoi
Cibotium glaucum

Hymenophyllaceae

Sphaerocionium lanceolatum
Vandenboschia davallioides

Gleicheniaceae

Gleichenia emarginata

Lycopodiaceae

Lycopodium cernuum
Lycopodium haleakalae

Marattiaceae

Marattia douglasii

Polypodiaceae

Asplenium contiguum
Asplenium lobulatum
Asplenium normalae
Asplenium schizophyllum
Athyrium microphyllum
Athyrium sandwichianum
Coniogramme pilosa
Cyclosorus sandwichensis
Dryopteris glabra
Dryopteris paleacea
Elaphoglossum hirtum Var. micans
Grammitis hookeri
Pleopeltis thunbergiana
Polypodium pellucidum
Pteris excelsa
Pteris irregularis
Sadleria pallida
Thelypteris stenogrammoides

Angiosperms

Apocynaceae

Alyxia olivaeformis

Aquifoliaceae

Ilex anomala

Araliaceae

Cheirodendron trigynum

Campanulaceae

Clermontia hawaiiensis
Cyanea sp.

Compositae
  Erechtites valerianifolia
  Eupatorium riparium
  Gnaphalium sp.
  Hypochaeris radicata
  Senecio sylvaticus

Cyperaceae
  Carex alligata
  Carex macloviana

Epacridaceae
  Styphelia tameiameiae

Ericaceae
  Vaccinium calycinum

Gesneriaceae
  Cyrtandra lysiosepala

Gramineae
  Anthoxanthum odoratum
  Axonopus affinis

Guttiferae
  Hypericum japonicum

Juncaceae
  Juncus planifolius
  Juncus tenuis

Labiatae
  Stenogyne calaminthoides

Leguminosae
  Acacia koa

Liliaceae
  Astelia menziesiana

Loranthaceae
  Korthalsella complanta

Myoporaceae
  Myoporum sandwicense

Myrsinaceae
  Myrsine lessertiana
  Myrsine sandwicensis

Myrtaceae
  Metrosideros collina subsp. polymorpha

Piperaceae
  Peperomia leptostachya
  Peperomia macraeana

Polygonaceae
Rumex sp.

Rosaceae
Rubus hawaiiensis
Rubus penetrans
Rubus rosaefolius

Rubiaceae
Coprosma rhynchocarpa
Nertera depressa

Rutaceae
Pelea clusiaefolia
Pelea sandwichiana

Saxifragaceae
Broussaisia sp.

Scrophulariaceae
Veronica plebeia
Veronica serpyllifolia

Solanaceae
Solanum nigrum

Umbelliferae
Hydrocotyle sibthorpioides

Urticaceae
Pipturus hawaiiensis

Report of phenological and growth studies, 1971

B-3
C. H. Lamoureux
J. R. Porter

The first part of this report deals with studies of species other than Metrosideros, while studies of Metrosideros which have involved about one-third of our efforts in 1971 are summarized at the end of the report.

During 1971 nine plots were established in Hawaii Volcanoes National Park and in the Kilauea Forest Reserve for the study of phenology, growth rates, and cambial activity in woody species (Table I).

In each plot 10 trees of each species are marked, and at monthly intervals circumferences are measured and phenological observations made on each tree. At the same time cambial samples are obtained from one tree of each species, both from the main stem and from small twigs. From 5 to 10 tagged twigs on one or two trees of each species in each plot are measured and mapped at monthly intervals to provide additional data on patterns and rates of growth.

A series of other species are examined in each plot at the time of each visit in order to provide further phenological information. About 40 species are involved, including ferns, grasses, herbs, and woody plants, in addition to the 12 woody species (Table I) which are studied more intensively.

Since we have less than one full year's observations from most plots, it is impossible to make definitive statements about phenological phenomena yet. However our studies have yielded enough data to enable us to suggest general sequences and durations of phenophases in some species, and have pointed out the need to continue our observations for a period of one or two years before we can draw any firm conclusions. A selected series of observations are reported here:

1. The phenology of Acacia koa was the subject of one previous study (Lanner, R. M. 1965. "Phenology of Acacia koa on Mauna Loa, Hawaii", U. S. Forest Service Research Note PSW-89, 10 pp.). A comparison of our data and Lanner's (Fig. 1) shows that in 1964 koa flowered most heavily between February and May, while in 1971 flowering occurred between October and December in the same areas. This suggests that we need to obtain much more data on flowering times in koa.

2. Baldwin studied flowering in Sophora chrysophylla on Mauna Loa and Kilauea in 1948-49 (Baldwin, P. H. 1953. "Annual cycle, environment and evolution in the Hawaiian honeycreepers (Aves:Drepaniidae)", Univ. Calif. Publ. Zool. 52:285-398). Figure 2 compares our data with Baldwin's, and shows that flowering patterns in 1971 were similar to those in 1948-49. In most areas flowering was heaviest in both years between October and March. However, our data show that in two localities, the highest and lowest elevations in our study, there was also a period of fairly heavy flowering in July, while Baldwin did not find significant numbers of flowers in the summer during the course of his study.

3. In Cheirodendron trigynum (Fig. 3), an evergreen species from montane rainforests, vegetative flush occurred between February and May, followed by flowering between March and August. Ripe fruit were observed between July and December. In this species inflorescences are borne terminally on new shoots.

4. In Diospyros ferrea (Fig. 3), an evergreen species from summer-dry coastal lowlands, new vegetative flushes were observed throughout the year, although there were fewer such flushes during the drier summer months. Flowering was observed from January through May and from November to December, but few or no flowers were found during summer months. Fruits in various stages of development were found throughout the year, but the largest number of ripe fruits dropped to the ground in November. In this species flowers occur singly in leaf axils, and buds develop irregularly (i.e., flowers do not open in regular acropetal or basipetal sequences). Thus one could find the following in consecutive leaf axils on a single twig: ripe fruit, flower bud, open flower, young fruit, ripe fruit, young fruit, flower bud.

5. Erythrina sandwicensis (Fig. 3) is a deciduous tree from the summer-dry coastal lowlands. Old leaves fall between March and June, followed by flowering from June through September with a peak in August, and a few trees flowering as late as October. New leaves are produced starting in November, after the onset of the wetter season. Fruits remain on the tree all year. These leguminous fruits open a few months after flowering, but the seeds may remain attached to the open pods for a year or more. Trees are leafless for four to five months, and flower while leafless.

6. Sapindus saponaria (Fig. 3) is a deciduous species which grows in Kipuka Puaulu at 4000 feet elevation. The climate is summer-dry but there are frequent fogs in the area in the dry season. In 1971 leaf-fall occurred between February and May, with new flushes of vegetative growth appearing between March and July. Vegetative flushing was followed by flowering between May and September. Full-sized fruits were evident by July, and some ripe fruits were falling in August. Some fruits remain on the plants as late as March, but usually all have fallen before new vegetative flushes occur. Individual trees are leafless for only one or two months, and flowering occurs after the new vegetative flushes.

Further studies will be necessary to determine if the patterns observed in 1971 are regular and occur at the same times each year.

Data for studies of growth rates and cambial activity are still being analyzed, but for most species it appears that the vascular cambium is active to some degree throughout the year.

Plans for 1972-73 include continuing monthly observations and sampling, and, time and funding permitting, extending studies to other species not now included. When data have been obtained for two years (by Jan. 1973), we will begin work on correlations between climatic data and phenological and growth data.

Metrosideros

During 1971, observations were made at intervals of four to six weeks, during eight visits to the HVNP plots. Two areas isolated by recent lava flows were eliminated from the study, and four new ones were established. There are now a total of nine plots for the study of Metrosideros trees. They are located at elevations of 50, 2380, 3370, 3920, 3990, 4025, 4120, 5150, and 7000 feet. The four plots near the 4000-foot level are located in different climates on various soil types (Table II). Observations of phenology and growth rates of marked trees were made. Cambial samples were taken. The predominant tree within the park is Metrosideros collina subsp. polymorpha var. incana, and 86 of 90 trees examined were of this variety, distinguished by pubescent leaves, twigs, and flowers. The other trees belong to glabrous or smooth varieties.

Cambial samples taken at every visit throughout the year showed that the vascular cambium is continuously active in all trees sampled at each location. The bark easily detached from the wood at the cambial zone although the intention was to keep the two tissues in contact during the sampling procedure. The portions of bark and wood were fixed in CRAF III fixative for later examination. A few samples studied in detail have shown that the cambial zone is only a few cells thick indicating very low activity and thus accounting for the slow rates recorded of 0 - 20 millimeters circumferential increment during the year. An intriguing discovery was that the trunks of the trees at most plots are flattened. In cross section they are elliptical in shape with the major axis running north-south.

During the past year, the greatest number of trees produced the largest numbers of inflorescences at 50, 2380, 4120, 5150, and 7000-foot elevations (Table II). Peak flowering occurred from April to July at these elevations with the exception of the 7000-foot elevation which had its peak from December to March. The other intermediate elevations had less intensive flowering. The peak at 3370 and 3990 feet was July, at 3920 feet was November to January, and at 4025 feet was January. The winter flowering peak occurred in the rainforest and the summer flowering peak in the summer-dry forest, at these intermediate elevations. On many trees at all elevations flowering continued for several months, with only one peak each year, a few have subsidiary peaks, still fewer did not flower.

Inflorescences are usually borne from axillary buds on recently formed twigs, the flowers within a single inflorescence blooming over a month-long period. The fruit capsules take six months or longer to mature.

Flushes occur several times a year on each tree. However, on any one twig only one flush occurs each year. This is in contrast to the flush-on-flushes that occur in several varieties on Oahu. Typically each vegetative flush consists of 10 paired leaves with the terminal bud not developing. In some drier areas, mainly outside of the numbered plots, trees bear long indeterminate shoots resembling lammas shoots.

Each normal, determinate flush takes about two months from bud break to hardening off. No correlation of climate to periodicity in flushing has been noted. Leaf fall occurs throughout the year.

Among other growth aspects studied were insect damage. Heavy attacks by various Lepidoptera on both vegetative and floral buds have caused much limitation to the growth potential, particularly during the summer.

Collaboration with other investigators: Closest collaboration has been with certain entomologists concerned with fluctuations in populations of insects related to specific plant phenophases. Projects C-4, C-5, and C-6 are most directly involved here and C-1 is involved in part. There is close cooperation with two botanical projects, B-6, genecological studies on Metrosideros, and B-8, roles of fungi. For example, in December 1971 we noted a conspicuous Penicillium which appeared to be decomposing the mesocarp of Diospyros fruits, large numbers of which had fallen to the ground during November. It will be useful to determine the role of this fungus in the ecosystem and to determine if there are seasonal fluctuations in the fungus population which can be correlated with fruit fall in Diospyros.

Relationships between this project and studies of birds (D-1) should be immediately apparent. Information from this project will also be of use in D-2, studies of small mammal populations. For example there may be seasonal differences in diets of small mammals, or perhaps even fluctuations in population sizes, which may be related to particular plant phenophases.

TABLE I

Information on plots for studies of phenology, growth rates, and cambial activity of woody species.

LOCATION	ELEVATION (FEET)	SPECIES STUDIED INTENSIVELY	MONTH PLOT ESTABLISHED	CLIMATE TYPE
Kalapana Section, Near Wahaula Heiau	25	*Erythrina sandwicensis* *Diospyros ferrea*	March	Warm-tropical Summer-dry
Kipuka Nene	3000	*Sophora chrysophylla*	January	Summer-dry
Thurston Lava Tube	4000	*Ilex anomala* *Coprosma ochracea* *Myrsine lessertiana*	May	Humid
Kilauea Military Camp	4000	*Santalum ellipticum*	October	Humid summer-dry transition
Kipuka Puaulu	4000	*Sophora chrysophylla* *Acacia koa* *Sapindus saponaria*	March	Summer-dry with frequent low clouds
Mauna Loa Strip Road	5150	*Sophora chrysophylla* *Acacia koa* *Dodonaea viscosa*	March	Summer-dry with frequent low clouds
Kilauea Forest Reserve	5400	*Acacia koa* *Cheirodendron trigynum* *Myoporum sandwicense*	March	Humid summer-dry transition

TABLE I

Information on plots for studies of phenology, growth rates, and cambial activity of woody species.
(Continued)

LOCATION	ELEVATION (FEET)	SPECIES STUDIED INTENSIVELY	MONTH PLOT ESTABLISHED	CLIMATE TYPE
Mauna Loa Strip Road	6000	_Sophora chrysophylla_ _Acacia koa_	November	Summer-dry with frequent low clouds
End of Mauna Loa Strip Road	6700	_Sophora chrysophylla_ _Acacia koa_	January	Summer-dry with frequent low clouds

TABLE II

Metrosideros plot locations and characterizations

NUMBER	LOCATION	ELEVATION	CLIMATE	SUBSTRATE	VEGETATION TYPE	PEAK FLOWERING	ABUNDANT FLOWERING
6	Kalapana	50'	Tropical summer drought	pahoehoe	Very open Metrosideros Diospyros forest	Apr.-July	+
13	Hilina Pali	2380'	Summer-dry	aa	Open Metrosideros Andropogon grassland	Apr.-July	+
12	Hilina Pali Rd.	3370'	Summer-dry	pahoehoe-ash	Metrosideros-native shrub	July	-
11	Thurston Lava Tube	3920'	Humid montane rainforest	moderately deep continuous ash	Closed Metrosideros-Cibotium fern forest	Nov.-Jan.	-
9	Mauna Loa Strip Rd.	3990'	Summer-dry-humid transition	pahoehoe-thin ash	Open Metrosideros-lichen with shrubs	July	-
10	Highway 11	4025'	Humid-summer-dry transition	pahoehoe-thin ash	Open Metrosideros-Sadleria fern forest	January	-
8	Kipuka Ki	4120'	Summer-dry, freq. low cloud	pahoehoe-deep ash	Mixed Metrosideros-Sapindus-koa forest	Apr.-July	+
14	Strip Rd.	5150'	Summer-dry, freq. low cloud	aa	Open Metrosideros-Sophora-Dodonaea for.	Apr.-July	+
7	Summit Trail	7000'	Summer-dry, freq. low cloud	weathered aa	Globous shrub-scattered Metrosideros	Dec.-Mar.	+

Flowering of Acacia Koa on Hawaii Island

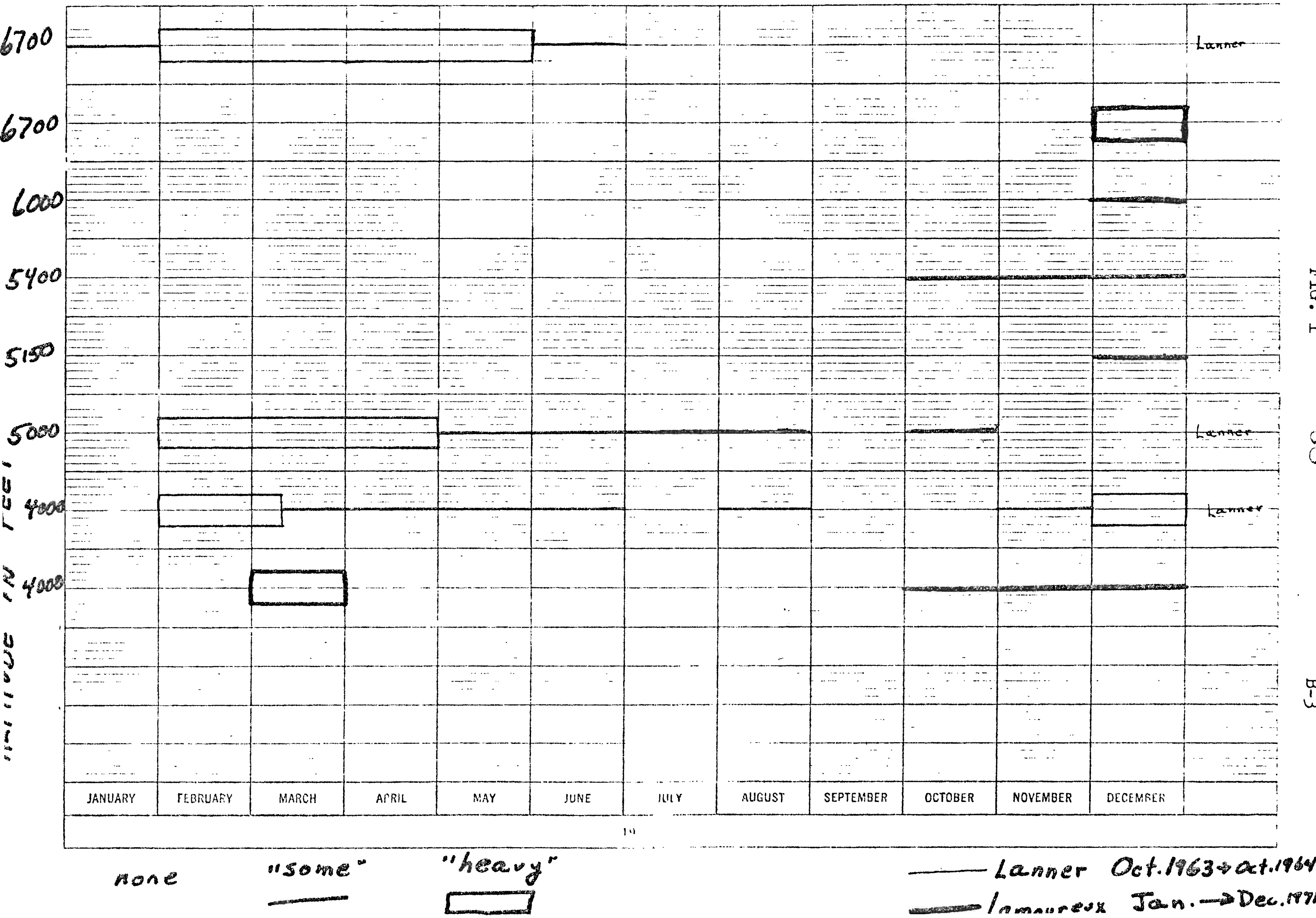

FIG. 1

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Flowering of Sophora chrysophylla on HAWAII Island

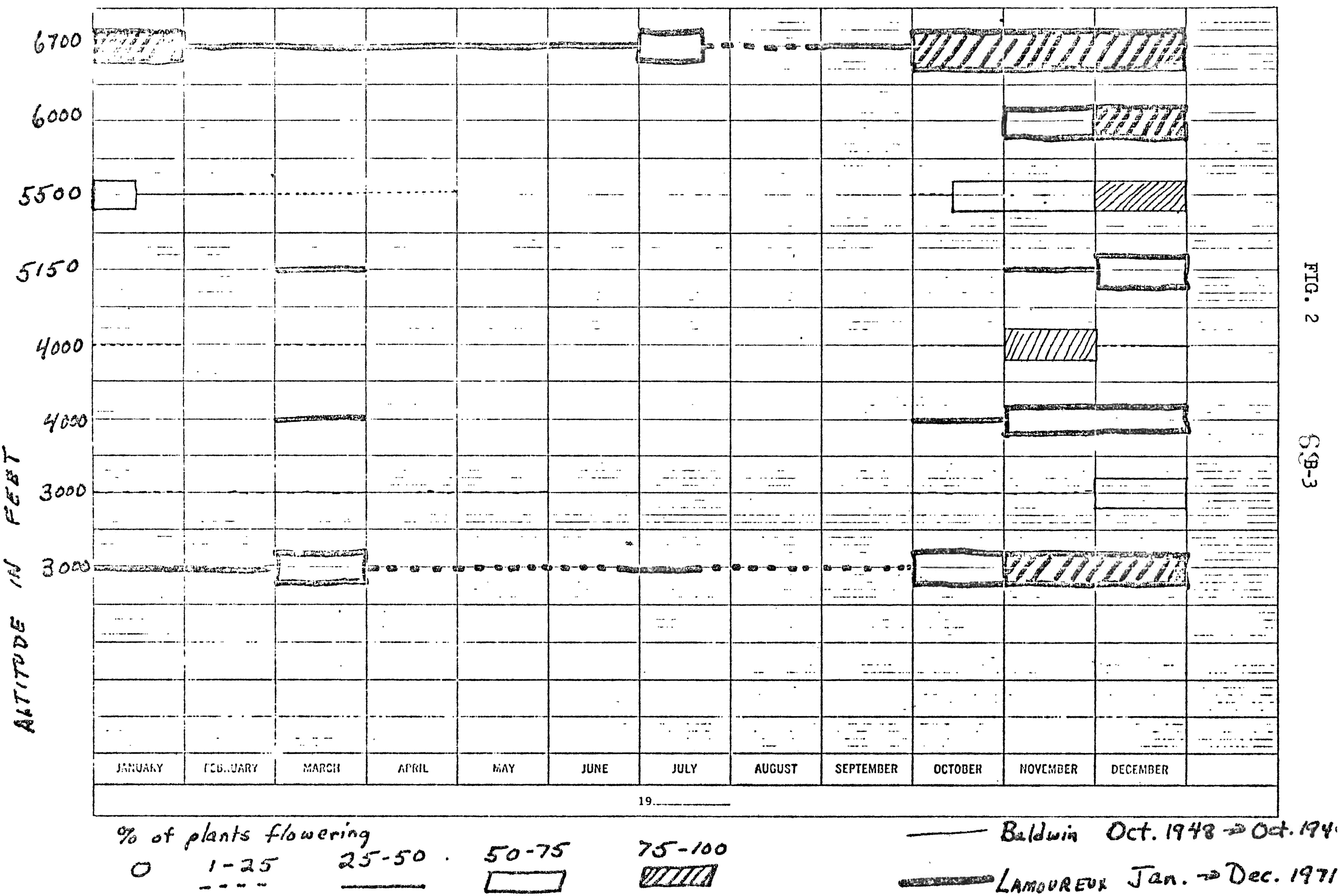

FIG. 2

B-3

Phenological patterns, 1971, Hawaii Island

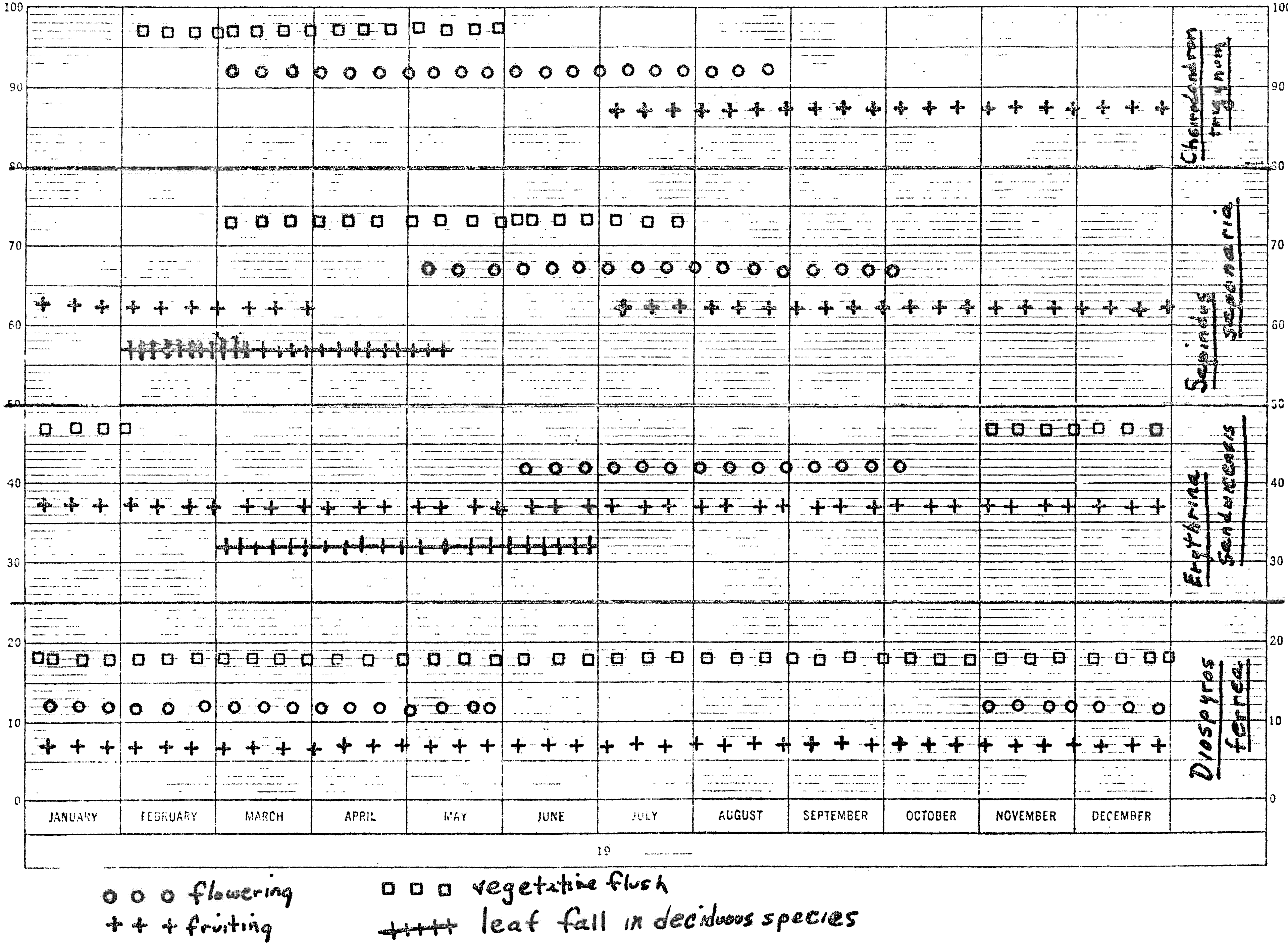

FIG. 3

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B-3

Studies on the autecology of two native Hawaiian tree species along IBP transects

B-4

The following two studies on <u>Acacia koa</u> (koa) were initiated particularly because of the interest of the Bishop Estate (a large landholding corporation in Hawaii) in this native tree species. Koa is intended for future use in Hawaiian forestry. The Bishop Estate, through the efforts of its chief forester, Mr. Norman Carlson, has supported this part of our IBP studies with additional funding, including the supply of a new jeep vehicle.

So far, very little information is available on the ecology of koa. Therefore, the following two studies on koa growth rates and reproduction will be of considerable practical and scientific information value when completed.

A knowledge of koa growth rates in relation to age is important information for the tree structural analysis of the Kilauea rain forest (subproject B-2a).

The koa reproduction study is done in two IBP study sites, the Mauna Loa Transect and the Kilauea rain forest site. Koa regeneration from seed was found only in the rain forest (Kilauea IBP study site) and not along the Mauna Loa Transect. Here, koa occurs in association with grassland.

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(a) Koa growth rates in relation to age

One of the outstanding problems in the silviculture of tropical trees is the absence of annual growth rings for determining tree-age. Acacia koa is no exception in this regard. Growth rings have been detected, but there is as yet no information whether these are in fact annual rings.

The size of trees is, of cource, related to age in some way. Yet, other factors, such as site with all its environmental parameters, biotic influences and stocking density may interfere. However, if the latter factors are taken into consideration, the age of a tree may be interpreted from its size. To achieve such an interpretation, it is necessary to study the growth rates of koa in different, well defined habitats, under comparable stocking densities and absence of interference from browsing.

Field procedure

Two montane forest habitats were selected, the Kilauea rain forest (about 2200 mm annual rainfall) and the summer-dry forest of Kipuka Puaulu (about 1500 mm annual rainfall; segment 9, Mauna Loa Transect).

In each forest a number of koa trees were carefully selected for average stocking density and range in size distribution from small to large. Size is measured from height and diameter. The koa trees were divided into 10 diameter classes. The smallest diameter class ranges from 0-1.5 inches, the largest from 45 inches to infinite. A minimum of 5 trees was selected in each diameter class in each locality. Each tree was labeled and the diameter of each tree was measured once a month (commencing mid-month in August 1971). The position of the diameter tape was permanently fixed for each monthly remeasurement by two nails at breast height. The height was also remeasured with each diameter remeasurement.

Data analysis

The monthly diameter measurements allow computation of the monthly diameter increment or growth rate. After one year, the annual growth rate can be established.

From these data it will be possible to calculate the time it takes for a koa tree to grow through each diameter class. For example, when a tree has grown through the first three diameter classes, one only has to add the time intervals that were required for this tree to achieve this diameter increase.

Age calculation

After knowing from repeated height measurements the time it takes for a small koa to reach breast height (4.5 feet), the age of a zero diameter-at-breast-height (dbh) tree is readily established. From then on, the time required for growth through the first diameter class into the middle of the second diameter class gives the mean age of a 1.5-3.0 inch dbh tree. This age is added to the time required for a koa at that habitat to grow through half of the third class to determine the age of a 3-5 inch tree, and so on.

Preliminary results

The first few monthly remeasurements have shown that koa diameter growth is slow in the smallest dbh class (0-1.5"), thereafter, its growth rate accelerates steeply to attain a peak at about 10 inches dbh. From that size on upwards the growth rate of koa decreases with minute increments occurring after it has reached 40 inches dbh. For the attempt to arrive at a reasonable age estimate of koa, it is important to realize that the growth rate varies with the size of the tree. There is no straight-line relationship between size and age.

Preliminary results also show that the peak growth rate (for ± 10 inch dbh trees) in the summer-dry forest (Kipuka Puaulu) is about half that of the koa growing in the rain forest (Kilauea Forest Reserve).

It would be premature to present actual growth and age values at this stage of the research. This will be done after the measurements of one annual cycle are completed.

G. Spatz
D. Mueller-Dombois

(b) Koa reproduction study

Acacia _koa_ has two means of reproduction, vegetatively from root suckers and sexually from seed. Reproduction from root suckers appears to be the only mechanism of koa survival and spread in the mountain parkland and savanna ecosystems along the Mauna Loa Transect. In contrast, reproduction from seed is the main mechanism of koa maintenance in the Kilauea rain forest.

An interesting question relating to ecosystem stability is: What stimulates and maintains koa suckering in the Mauna Loa Transect ecosystems and what prevents koa from applying the same vegetative mechanism in the rain forest habitat?

We, therefore, started an investigation into the factors associated with these different ecosystems that could be responsible for causing reproduction from either seed or root.

The ecosystem differences expected to be most important were:

1. Amount of rain fall
2. Soil moisture and soil depth
3. Associated vegetation
4. Animal influences
5. Seed availability and viability

Koa germination study

Initial efforts went into establishing seed germination tests in the three ecosystems: mountain parkland, savanna and rain forest.

Some information on koa seed germination was previously reported by Judd (1920) and Bryan (1929). They found boiling water treatment to be a useful method of koa seed scarification. Similarly, Whitesell (1964) reported that placing koa seeds in hot water for soaking is a good pretreatment for successful germination, but he also stated that seed will germinate readily under favorable conditions. These were stated as bare mineral soil and exposure to light. But Whitesell also pointed out that no specific germination tests were reported so far. Many authors declare that koa can never survive in shade (Hall 1904, Hatheway 1952, Russ 1929, Judd 1920).

Areas of about 2 x 2 m were freed from plant cover by scalping and the mineral soil was exposed. These test plots are kept free of plants throughout the experiment. Thirteen such test plots were established, of which four were fenced against goats. The four fenced test plots are in the following locations:

1. 6650 ft., Mauna Loa Transect, Rain Shelter
2. 5300 ft., Mauna Loa Transect, Climatic Station
3. 4200 ft., Mauna Loa Transect, Kipuka Ki
4. 5400 ft., Kilauea rain forest, Climatic Station

Test plots 1 and 2 are in the mountain parkland ecosystem; test plot ... the savanna ecosystem, but next to a closed Kipuka forest. Three un-...d germination plots of the same size were established, each in site 1, and at 2200 feet near Hilina Pali Shelter.

Each germination test plot was divided into 2 halves, one half showed ...sed mineral soil, the other half was covered with litter mulch.

The more immediate test questions asked were:

1. Which environment is the most favorable?
2. Does exposure to light influence koa germination?
3. Does sowing depth influence the germination results?
4. Does seed origin influence the germination results?

The four questions could only be answered from the fenced test plots. The first question was answerable through the four different test plot locations and environmental records of rainfall, altitudinal temperature and soil moisture. Questions 2-4 were answerable from each individual test plot.

Two hundred seeds were sown in each test plot into equally spaced individual positions. Four sowing depths were used: 0, 1, 3 and 7 cm. Each sowing depth was replicated 5 times with each 10 seeds. Koa seed was obtained from 5 locations: (1) Kilauea forest 5400 feet, (2) Mauna Loa Transect between 4000-4500 feet, (3) between 4500-5000 feet, (4) between 5000-...00 feet, (5) between 6000-6650 feet (= upper limit of mountain parkland ecosystem). Seeds from these 5 different locations were sown in each test plot in 10 rows, each row containing 10 seeds. Five of the 10 rows were covered with a layer of litter mulch.

Preliminary results

Overall germination was rather low. The maximum was 10%.

Table 1 shows that a higher germination and survival occurred in the locations with greater rainfall, Kilauea forest and Kipuka Ki (Mauna Loa Transect, 4200 feet). Upward the transect, germination and survival decreased. No survival occurred at the highest location (6650 feet, Mauna Loa Transect).

Germination occurred in both, uncovered and covered parts of each test plot. This indicates that light is unimportant for germination. However, survival under litter mulch occurred only at one location, in the Kilauea rain forest, the moistest location. This indicates that seedling growth through litter to reach light must be fast for survival or that litter must be shallow.

No germination occurred at zero sowing depth in the uncoverd sections. The best of sowing depths were 3 cm and 7 cm in the uncoverd sections. In the covered sections, the most successful sowing depth was at 1 cm. This indicates that soil moisture is very important, perhaps the most important factor for koa germination.

Table I: Preliminary results of Koa germination tests

	germinated seeds									surviving seedlings								
	uncovered				covered					uncovered				covered				
sowing depth	0	I	3	7	0	I	3	7	total	0	I	3	7	0	I	3	7	total
origin of seed																		
Kilauea Forest Reserve 5,400 feet elevation																		
Kilauea Forest																		
5,400'		•	••	•					4		•	•	•					3
4,000-4,500'				•					I				•					I
4,500-5,000'				•		•			2						•			I
5,000-6,000'		••	••			••		•	7			••			•		•	4
6,000'		•	•						2		•							I
total		4	5	3		3		I	I6		2	3	2		2		I	IO
Strip Road Shelter 6,650 feet elevation																		
Kilauea Forest																		
5,400'							•		I									0
4,000-4,500'			•				•		2									0
4,500-5,000'					••				2									0
5,000-6,000'			•••						3									0
6,000'		•			•				2									0
total		I	$\boxed{4}$		3		2		IO									0
Strip Road 5,240 feet elevation																		
Kilauea Forest																		
5,400'				••	•	•			4				•					I
4,000-4,500'									0									0
4,500-5,000'				••		•			3				•					I
5,000-6,000'		•		••	•	•	•		6		•							I
6,000'						•			I									0
total		I		$\boxed{6}$	2	4	I		I4		I		2					3
Strip Road 4,200 feet elevation																		
Kilauea Forest																		
5,400'			•			•		•	3			•						I
4,000-4,500'			••	•				•	4			••	•					3
4,500-5,000'				•		•			2				•					I
5,000-6,000'			••	••		••	••	•	9			•	•					2
6,000'				•		••			3				•					I
total			5	5		6	2	3	2I			4	4					8
total		6	I4	I4	5	I3	5	4	6I		3	7	8		2		I	2I

Survival was best with 63% in the Kilauea rain forest and decreased ...kedly in the summer-dry climate along the Mauna Loa Transect. Here, ...rvival was 38% at 4200 feet (Kipuka Ki), 21.5% at 5240 feet (Climatic ...tion) and zero at 6650 feet (Mauna Loa rain shelter). This is closely ...ated to soil moisture fluctuations, with the greatest soil drying occur... at the highest location.

...ed origin (Table 2)

None of the five seed origins were failures. But the best germination ...curred from seed collected between 5000-6000 feet along the Mauna Loa ...ansect. The second best germination was from Kilauea forest. Thus, seed ...rom 5000-6000 feet elevation seemed most vigorous regardless of whether ...t was obtained from rain forest koa or from koa growing in summer-dry cli...ate. This would indicate temperature to be more important for seed via...ility than rainfall. However, the results are not yet conclusive because there may be year to year or individual tree variations.

The germination and survival experiments will be continued.

...oa sucker reproduction study

Five scalped strip plots of about 10 x 1 m were established at 3 locations (Mauna Loa Transect 6600, 6200, 4000 feet) to study vegetation recov...ery and koa sucker response following ground disturbance. Such disturbances ...ccur at many places in the mountain parkland and savanna ecosystems from pig scarification.

Preliminary results show that in the mountain parkland ecosystem koa ...uckering occurs more or less continuously without stimulation from ground ...r root disturbance. The Mauna Loa exclosure study (see B-1a) shows that ...oa suckers grow profusely at the perimeter of koa stand colonies simply ...y removing the interference from goats. But suckering occurs just as ...rofusely under goat feeding pressure with the difference that the suckers ...re kept at ground level without a chance to grow into trees.

In contrast,in the savanna below the mountain parkland, koa suckering ...oes not seem to occur without stimulation from ground disturbance. One of the scalped strips in this ecosystem showed 2 koa suckers that emerged recently. A pig-scarified area nearby similarly resulted in koa suckering.

Two related factors seem responsible for this differential response in koa suckering. In the savanna ecosystem, the soil is generally deeper than 1 m. The grass biomass per unit area is much greater here than in the mountain parkland. Also, the roots of koa are not forced to grow as close to the soil surface as in the mountain parkland, where soil depth is generally less than 1 m.

Therefore, low biomass of grass cover and shallow soil depth seem to promote koa suckering.

However, this correlation does not explain why root suckering is so rare in the Kilauea rain forest, where the soil is also shallow and the herbaceous ground cover almost absent. The koa suckering study is therefore continued.

Table 2: Influence of seed origin

origin		seeds germinated Kilauea Forest	Strip Road 6,650'	5,240'	4,200'	total
Kilauea Forest 5,400'		4	I	4	3	I2
Strip Road	4,000-4,500'	I	2	-	4	7
//	4,500-5,000'	2	2	3	2	9
//	5,000-6,000'	7	3	6	9	24
//	> 6,000'	2	2	I	3	8

Report on fern study. R.M. Lloyd

Four days were spent on the Big Island in order to visit specific areas and choose possible sites for establishment of permanent plots for study. (10/31-11/3,1970). The entire area covered included the volcano area, the south portion of the Chain of Craters Roa d the the Saddle Road. Four tentative locations for future work were selected. It is expected that two or three more will be added to this list in the future. Those selected are as follows:

1. IBP study area, about 10 miles north of Volcano
2. 1955 lava flow in Puna District on highway 13 at road to Opihikao
3. 1750 lava flow on highway 13, 0.85 miles north of intersection of routes 13 and 137 (at Kaima)
4. 1855 lava flow on Saddle Road, 19.8 miles west of intersection of routes 19 and 20, on route 20.

In addition to site visits, spore collections and herbarium voucher specimens were taken of 33 individuals, representing the major fern species which predominate at each of these locations. These include species of Nephrolepis, Sadleria, Polypodium, Cibotium, Pteridium, Dicranopteris, Dryopteris, Microsorium, Asplenium.

In addition, a visit was made to the fumerol area 300 m south of Puhimau Crater and a collection of Schizoloma cordatum Gaud. was made.

Carolyn Corn
G.C. Ashton

Genecological studies on Metrosideros.

Branch specimens with ripe capsules are being collected for taxonomic identification, seed germination, gel electrophoresis, and progeny tests. Collections so far include plants from windward Hawaii, Maui, and Oahu. Once the fertile seeds from the collected capsules are given light and water, they germinate in 4-6 days. They grow well in diverse substrates, such as laterite, sand, tree fern, sphagnum moss, vermiculite and perlite. The standard soil substrate being used is 1:1:1 sphagnum moss, tree fern, and top soil. The three month old seedlings are growing very slowly, and are about an inch in height. They will soon be large enough to pluck off leaves for gel electrophoresis tests, and are beginning to show individual morphological differences that will be recorded in the progeny tests.

Germination

Branches that have ripe unopened capsules are collected from trees at different elevations. Then each branch is identified according to Rock's revision of the genus. The mature capsules on the branches are air dried until each capsule splits longitudinally along three carpels exposing a multitude of small seeds ranging from 1/2 to 3 mm long. The seeds germinate readily when placed on moist filter paper in petri dishes with a light source. The percent germination for each plant is recorded in figure 1 according to the variety that the seed came from. Individual plants of the same variety exhibit a large amount of variation in their germination. For instance, the most collected variety, typica, has 0 to 74 percent germination. Average germination is indicated by squares, and if additional trees are sampled, average germination per variety may be relatively constant.

In figure 2 the germination of the seeds is plotted according to the elevation that they were collected. The dark circles indicate windward Maui and the open circles indicate windward Hawaii (i.e. Mauna Loa and the Saddle Road) collections. Percentages can vary greatly at one locality, for instance at 4000 feet, 1 to 74 percent germination may be found between trees. The reason for the variation is not known, although further investigations will possibly show a close correlation between the number of flowers blooming per unit area and the number of viable seeds. Average germination at each elevation is indicated by squares. These averages may be smoothed out by using more trees, at $\pm$ 1000 feet elevation from those recorded in the graph. This gives a rather flat line that dips at the upper and lower elevations.

The genus survives from an area just behind the salt spray zone at sea level to 8300 feet on Mauna Loa. Although more samples will have to be otbained from the extreme elevations, the data in figure 2 indicates that Metrosideros is less able to produce numerous offspring at the extreme localities of the Kau Desert (200') and upper Mauna Loa (7500' to 8300'). These areas seem to be marginal spots where the genus is just able to survive and produce a few flowers and viable seeds a year. Precipitation is recorded as 30 to 40 inches a year with an unrecorded amount

Figure 1.

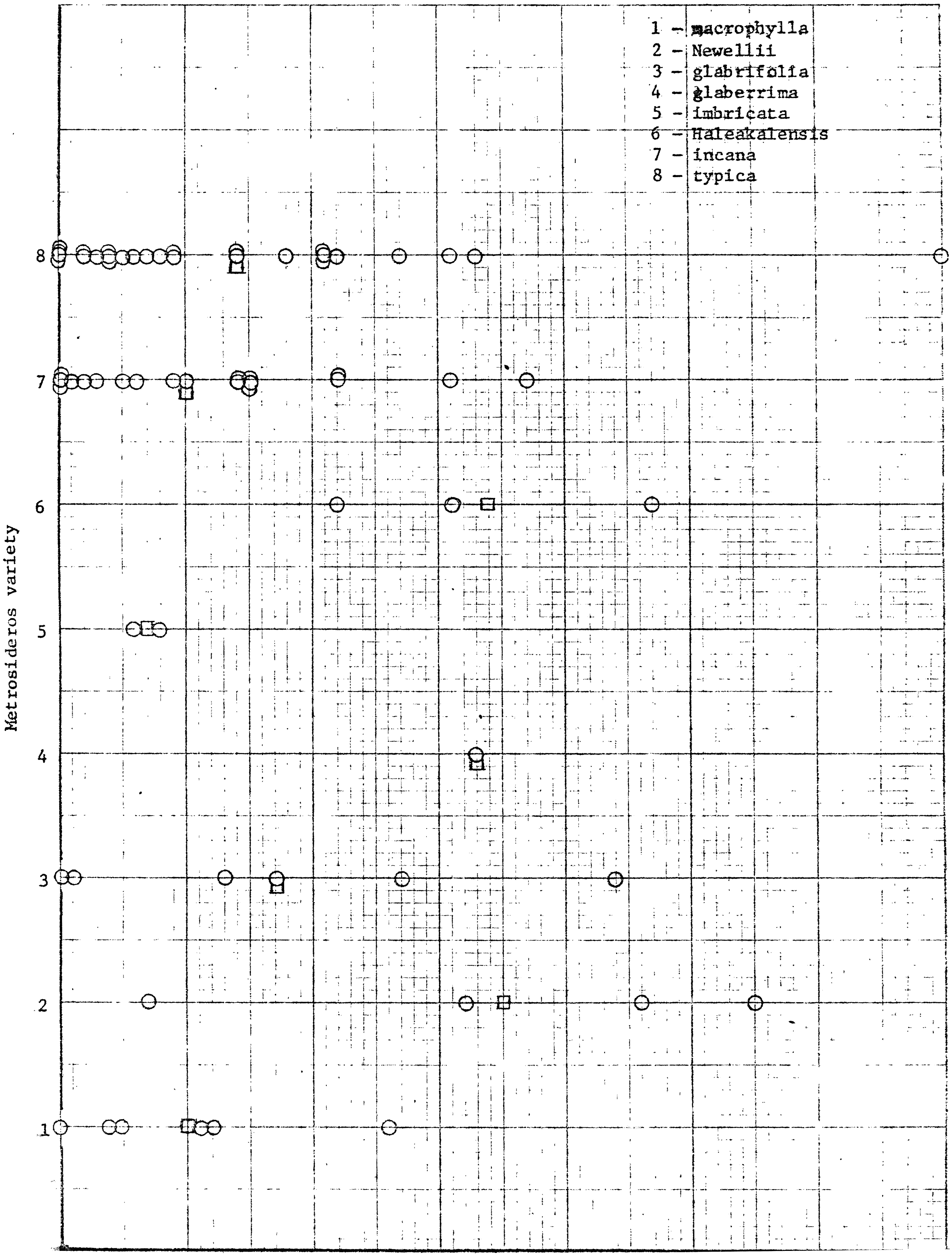
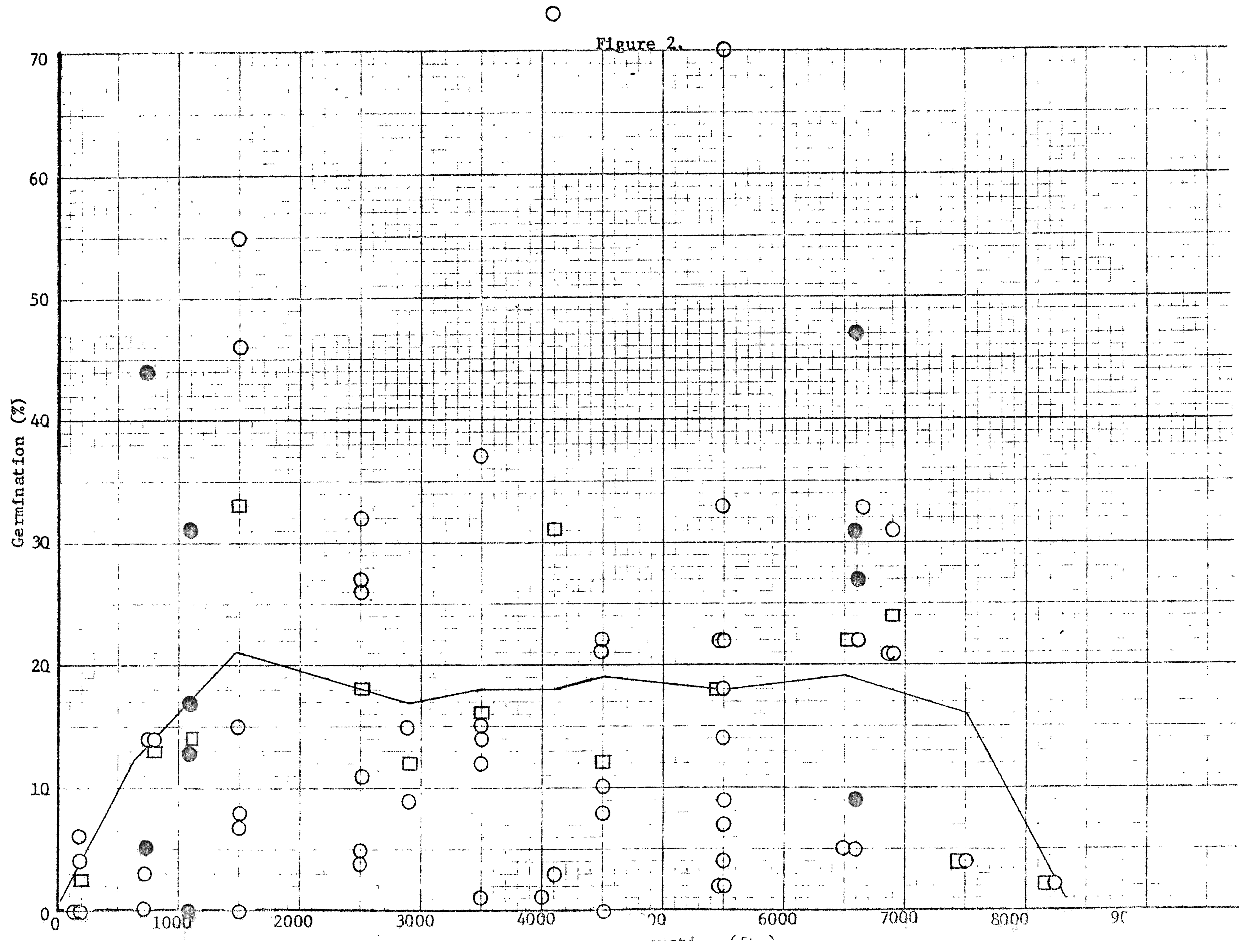

1 – macrophylla
2 – Newellii
3 – glabrifolia
4 – glaberrima
5 – imbricata
6 – Haleakalensis
7 – incana
8 – typica
Metrosideros variety
8
7
6
5
4
3
2
1

Figure 2.


Germination (%)
70
60
50
40
30
20
10
0
0
1000
2000
3000
4000
6000
7000
8000

of dew formation and drip at night. Both areas have very little cloud cover and large daily temperature fluctuations. Very few birds frequent these areas and strong winds are common. Here Metrosideros is the only surviving tree species with individuals spaced from 20 to 1500 feet apart.

Pollination

Pollen is found frequently on the stigmas of Metrosideros flowers, yet few observations have been made on how the pollen travels from anther to stigma. Various bird and insects visit the blossoms. Unfortunately in many areas new introduced insects and birds are taking over the pollinating role. For instance, the introduced honeybee Apis mellifica is now the chief pollinator on Oahu and many parts of the outer islands. This makes observations of important native pollinators difficult. Also, many spots in the mature forests are hard to observe since the blossoms are high off the ground with tree fern fronds blocking one's vision. Therefore, my preliminary observations are largely from lava flow areas and ridges where the trees are small and accessible.

On the island of Hawaii very few introduced honeybees are seen along the Chain of Craters Road and Mauna Loa Strip Road. This makes it a good spot for pollination studies. At the two extreme Metrosideros localities, Kau Desert and upper Mauna Loa, very little bird activity is seen. A native bee (Nesoprosopis sp.) gathers nectar in these areas from various flowering species. When the bee lands on a Metrosideros blossom it either lands on the stamens and moves down the style or perches on the side of the flower and probes into the flower's base without rubbing against the anthers. Each flower has a bee visiting it every few minutes when there is clear sky and not too strong a wind. None of the native bees collected had visible pollen attached to their bodies. When these same plants are checked for seed germination they range from 0 to 6 percent germination. These factors indicate that these bees are not effectively pollinating these plants.

On the Palikea-Mauna Kapu Ridge of the Waianae Mountains in Oahu a native wasp, Polistes exclamans, is seen visiting Metrosideros blossoms only on mornings that have full sunlight before 11 AM. The same plants are frequented by the introduced honeybee which also visits these blossoms. However, the honeybee accumulates pollen as well as nectar. The honeybee's surface area is covered with pollen and is undoubtedly a far more effective pollinator than the wasp visitor. On each trip the honeybee moves from flower to flower on the same tree rarely visiting nearby trees. The honeybee's behavior of gathering food from a profusely flowering tree probably is resulting in a large amount of inbreeding in these ohia trees. Before the arrival of these honeybees in 1857, a large amount of flower visits are attributed to the Hawaiian honeycreepers which move from tree to tree gathering food, thereby increasing the chances of outcrossing in the trees they visit. In fact, the honeybee appears to be so effective in its ability to obtain nectar and pollen, it may be robbing the honeycreepers of their food and causing them to decrease in number.

A small amount of pollination may be occurring by wind. The pollen is very sticky which would indicate that it is not wind blown. However, the absence of insect and bird pollinators in extreme elevations; wind causing closely associated flowers to rub together; and the fact that some fertile seeds are being set (0 to 6 percent); makes one suspect that wind plays a small part in the flower's pollination.

If one puts a pollination bag over an inflorescence of buds, no seeds are produced. Also, if the flower is de-staminated and bagged, no seeds are produced. These experiments, plus the fact that a variable percent germination takes place from one tree to the next (0 to 74 percent), makes me suspect that there is little or no apomixes occurring in the genus.

The timing of maturity of the male and female parts plays an important role in the outcrossing of the plant. The stamens and styles are positioned in a way that the stamens mature first, then the style elongates and matures slightly below, at the same height, or slightly above the anthers. This variation in stylar to stamen length gives the plant elasticity in pollination behavior. In good weather the stamens are intact at the time of stylar maturity, although if the weather is rainy the stamens fall off sooner.

Birds are probably the most important factor in Metrosideros pollination within the rainforests. However, no direct observations can be cited yet.

Techniques are presently being worked out for preserving fresh pollen by freezing techniques for later crosses. Also preliminary crosses are being made to establish the exact timing of stamen to stylar maturity. Once these techniques are established, crosses between various varieties will begin.

Transplants and clones

A technique is being sought whereby each variety can be reproduced vegetatively and planted in a common environment with other varieties. However, the genus is difficult to root. Normal horticultural rooting techniques using branches do not work. Also air layering induces callous formation with no root formation. Chemicals, including anti-auxins, are being tried to induce this callous tissue into root formation.

Fire

Metrosideros trees of 35 to 40 feet in height were burned by fire resulting from new lava flows in August. Foresters fighting the fire described the fire as burning along the ground in Andropogon grass then burning up through the occasional trees. A month later the capsules on these trees had dried and split open with the wind actively dispersing the seeds onto the cooling lava. However, no seed germination was obtained when the mature capsules from three burned plants were collected from 3 to 5 feet off the ground. The fire on and next to the lava flow was probably too hot. Seed introductions that will serve as pioneer plants on the lava flow will have to be made from a greater distance away from the flow or from a later crop of seeds produced from those trees that recover from the fire.

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First activity report on algae study. M. Doty

I. Two field trips to the major transect area involving six man days' time have been made. In addition major collaborators, e.g., Drs. Malcolm Brown and I.A. Abbott, have inspected the Park area in order to better devise their possible roles.

II. The initial taxonomic work is underway. It was initiated by collection and processing of 60 trappings spaced from +50 feet elevation (the bluff edge) to +6500 feet elevation (upper end of Mauna Loa Truck Trail), several months apart and from the initial 30 of which 41 separate unialgal cultures have been made. Preparations are completed for making another similar lot of isolates from the trappings made on the second field trip.

This work is expected to be completed next year in collaboration with Dr. Malcolm Brown who spent a day in the Park and several days in Honolulu making arrangements for this work. This entailed a special trip to Hawaii by Dr. Brown at no expense to the Hawaii IBP.

III. The techniques for quantitative sampling of the algal communities are being assembled. A sonicator has been obtained for this purpose (it arrived 3.XII.70), and experiments on trapping have led to the second trapping being conducted with much improved results. Further developmental studies are currently underway. Two graduate students may become involved in this; at least they have shown an interest in beginning next semester. A third student is expected to begin next summer.

IV. Planning with Dr. Brown and the graduate students has led to compiling the following budget for our needs during 1971-72. (see "Second-year budget")

Progress report on roles of fungi. Gladys E. Baker.

Ecological roles of fungi

In the original proposal the principal investigators emphasized the unique character of the biota in the Hawaiian Archipelago, the islands having served as an area of "spectacular evolution under extreme isolation" (p. 1, Abstract). They further note that Hawaiian endemic forms are unable apparently to compete and survive under the circumstances of current conditions (increased human population, introduced plants and animals), and that we should understand the original native environment in order to use it wisely and preserve it. Toward this end 4 common objectives were given for a number of investigators concerned with different disciplines including mycology (B-8).

To fit mycology into this program more pertinently some rearrangement of ideas expressed in B-8 is necessary, for this statement was prepared while Dr. Baker was on sabbatical leave. Fungi by virture of their constant adaptability, ability to survive for long periods of inactivity, and ease of dissemination do not necessarily provide the best material for a study of speciation and rate of evolution. Finding endemic fungi probably depends on demonstrating their dependence on other endemic organisms. Their role in stabilizing or contributing to fragility of ecosystems is important, as stated in B-8, but if based on parasitism will be difficult to demonstrate unless this is evidence for epiphytotics. A study of parasitism is properly the province of plant pathologists, and it is suggested that such an extension of this program be made sometime.

Variation and differences in fungal populations can be used as indicators for significant trends in the vegetation cover. Among the many fungal habitats related to the vegetation, the phyllosphere and rhizosphere are probably the most important as these would display the closest association with the plants. Air mycota, soil mycota and fungi of the litter zone must be considered but possibly only as contributors to the major populations. In any of these populations it is important to evaluate the members as permanent (living and active) and as transitory species. Soil fungi fluctuate between these two states depending on nutrients available. Those of the litter zone exhibit succession correlated with decay. Phyllosphere fungi show succession correlating with senescence.

Since very little data is available, the program will start with the selection of sites and suitable endemic plants. Comparative studies of the mycota in the phyllosphere and rhizosphere will be in order then for populatinns characteristic of the endemic plants with those of introduced plants and those in areas exhibiting change in the vegetation cover (cutover areas, e.g.).

These studies begin officially January 1, 1971, with the appointment of Mr. B.K.H. Lee as research assistant. A "head start" has already been made. Mr. Lee accompanied Dr. Mueller-Dombois and his group to the island of Hawaii September 24-25, 1970. He used Plot 1, Kilauea Forsst for samples of soil, litter, dead wood, fern rhizome and living leaves of _Cheirodendron_ sp., _Acacia koa_, _Metrosideros_ sp. To date, results of analyses show a higher number of species in the soil, but a much more unique mycota in the phyllosphere population.

Since the initiation of this program Dr. Goos has left the University of Hawaii. Therefore, a second research assistant is requested for the seond year as the volume of work involved is too much for one to accomplish successfully.

D. Elmo Hardy
M.D. Delfinado

Progress report on Diptera project.

Because of the shortage of funds this project has been limited to a study of Diptera breeding in fresh water habitats. These environments are extremely important in gaining an understanding of the evolutionary development of the Hawaiian biota. Many remarkable groups of flies have speciated in aquatic habitats and we feel it will be possible to chart their evolutionary development from the primitive marine forms to those which are now restricted to special niches in fresh water streams.

One graduate student, Joaquin Tenorio, is assigned to this project and is using part of the study for his Ph.D. thesis. He is doing a biosystematic study of the Hawaii Ephydridae and has conducted intensive surveys of these flies throughout the Islands (partially supported by IBP). Knowledge gained from these studies should be especially useful for evolutionary studies since a number of endemic species have developed in fresh water and show obvious relationships to marine species. These flies have adapted to a wide assortment of freshwater habitats and have apparently remained remarkably stable compared ot other Diptera, such as Canaceidae which have "invaded" the fresh water streams from the ocean and have speciated by Islands and in some cases by streams in special niches in fast flowing water.

Mr. Tenorio has now recorded 43 species of Ephydridae in Hawaii. He has biological data on approximately half of these and has done detailed biological studies on most of the endemic species. The systematic studies will be incorporated as a chapter in the Insects of Hawaii, vol. 13 Diptera Acalyptratae which is now being prepared.

Under IBP support a survey of the faunas of streams in the Kohala mountains and the Wailuku river, Mauna Kea, Hawaii was made. This was to compare the faunas of streams flowing off the Kohala Mts. (overland streams) with a stream which results from seepage from the rainforest on the mountain (Mauna Kea).

This survey gave much valuable data, we found seven families of flies, represented by at least 17 species living in close association in the fast flowing water and obtained biological data on ca. eight species belonging in three families. Two of the genera, Telmatogeton Schiner and Procanace Hendel (Chironomidae and Ephydridae) are maritime breeders in other parts of the world; living on wave swept rocks along rough seacoasts over much of the world. In Hawaii these have invaded fresh water, have adapted to breeding in fast flowing streams and are very restricted in distribution and habitat.

The Chironomidae are known to have polytene chromosomes so the Telmatogeton should be excellent for genetic studies and it is anticipated that studies of the aquatic Diptera should be extremely important in gaining an understanding of speciation. Preliminary investigation of Neoscatella (Ephydridae) indicate that these have good metaphase chromosomes and genetic technics may be useful in working out the evolutionary development of this group.

Preliminary surveys of the aquatic flies have now been conducted on all of the islands. Now we need to do specific habitat studies in as many of the streams as possible. Techniques need to be worked out for rearing as many of the species as possible. A simulated fast flowing stream habitat has been constructed in the laboratory and it is hoped that we may be successful in bringing materials in from the field and rearing species under laboratory conditions.

We have found to date eight families and at least 30 species of flies associated with fresh water streams in Hawaii. Most of these are native and at least half are undescribed. The preliminary studies have provided data concerning habits and biologies of many of these and much of the ground work has now been laid for doing genetic, and other refined studies, involving the aquatic Diptera.

Progress report on Sciaridae project. W.A. Steffan

One field trip was taken to the Kilauea Forest Reserve study site. The primary purpose of this first trip was to survey the study site in order to determine which sample techniques would be feasible for population studies of Sciaridae.

Four sampling techniques were used and the r esults from each are listed below.

1. The Malaise Trap; since it was up continuously, has yielded the largest number of species and specimens. The first week about 70 Sciaridae were collected, the second week about 80, and the third and fourth weeks combined about 400. Only the first collection has been identified and yielded the following specimens.

   a) Sciara hoyti (Hardy)
   b) Spathobdella setigera Hardy
   c) Ctenosciara hawaiiensis (Hardy)
   d) New species #2 (unplaced)

2. The CDC Miniature Light Traps were set up both in the Kilauea Study Site and in Bird Park. Fewer specimens were taken but they were alive and could be used in the genetic studies. Bradysia n. sp. #4 was taken in both areas along with other nematocerous Diptera.

3. The most productive for short sample periods and the most suitable for the conditions found in the Kilauea Study Site was a 1-meter square of unbleached muslin placed on various substrates for 1-2 hours. One sheet yielded over 30 live adults of the 3 species listed below. Note that Hyperlasion magnesensoria has not been collected in the Malaise Trap.

   a) Sciara hoyti Hardy
   b) Hyperlasion magnesensoria (Hardy)
   c) Spathobdella setigera Hardy

4. Sweeping yielded only two species, one of which has not been collected as yet by any other method.

   a) Ctenosciara hawaiiensis (Hardy)
   b) New species #1 (unplaced)

Laboratory studies have involved culturing as many of the Hawaiian Sciaridae as possible and have been very successful. The following species have been successfully reared for at least one full generation:

1. Bradysia radicuum (Brunetti)
2. Bradysia spatitergum (Hardy)
3. Bradysia tritici (Coquillett)
4. Bradysia impatiens (Johannsen)
5. Bradysia n. sp. #4
6. Sciara molokaiensis Hardy

7. *Scatopsciara nigrita* Hardy
8. *Lycoriella* n. sp. #1
9. *Lycoriella* n. sp. #2
10. *Plastosciara brevicolcorata* Hardy
11. *Plastosciara* sp.
12. *Scythropochroa* n. sp. #1
13. *Hyperlasion magnesensoria* Hardy

Collaboration with other invesigators has been very satisfactory and includes the following participants:

1. Dr. G.E. Baker has agreed to identify the fungi associated with Sciaridae.

2. Dr. Y.K. Paik plans to do population studies of *Bradysia impatiens* and *Bradysia tritici*.

3. Mr. William Steiner will use the Hawaiian Sciaridae for his graduate studies. This will involve biochemical techniques similar to those used by Johnson in his study of *Drosophila* esterases.

4. Dr. D.E. Hardy's Drosophila group has provided several collections of Sciaridae from their field collections.

5. Mr. W.C. Gagné has also provided a large collection of Sciaridae from his field collections.

Interim report, fieldwork on Big Island. J.L. Gressitt

21-22 Nov. participated in general surveys in parts of the Mauna Loa transect.

21 Nov., Plot 32. Sparse Metrosideros on old a'a-pahoehoe areas at 180m. Marked trees by Lamoureux, Nishida-Haramoto. Lower Chain of Craters Road, below lava.
Under bark: silver fish (Thysanura) - 2 adults; some young seen
centipede (Scolopendra ? spinipes) - 2 adults
geckos (dark brown) - 2

Plot 5. Naulu Forest, 1550 m.
Diospyros (dead) trunk: Lepidopt. larva borers (several)
Metrosideros (un. bark): Millipede - 1
Centipede (Scolopendra ?spinipes) - 1
small cockroach - 1
red prostigmatic mite - 2
(on bark): gecko (black) - 1
cockroach parasite (Ampulex) - 1
Aleurites (on bl. buds): small coccinellids (2)
Cocculus (Menispermac.): leaf-miner in leaves - mod. abundant

Plot 33. Below Naulu, mod. sparse Metrosideros-Diospyros forest, 330m
Metrosideros stems: scale insect (wax scale)

Kipuka Ki. Plot 39. 1260m.
Acacia koa: dead fallen branches on road; kept in box at Hdq. house for rearing: contain Diptera and Coleoptera larvae; case-bearing (flat) Lepidoptera larvae; minute adult beetle (?Cucujidae).

22 Nov. Park headquarters vicinity: medium-sized spider on ohia.
Hilina Pali Road near Chain of Craters Road: psyllid in ohia leaf galls abundant
"Hot spot" off Chain of Craters Road: Medium large spider, on fringe
Isopod "
small moths (2 spp.) near center, flying

23, 25 Nov. in Kilauea Forest Reserve study area beyond weather station (lower). (24 Nov. spent on reconnaissance with Bianchi in Kulani Prison area; climbed Kulani Cone tower for view of Kilauea Forest Reserve and environs; went to bulldozed areas, including Twin craters with silted unique lake, etc.; also Army nerve gas experimental area in forest reserve).

Study area: Set up an additional Malaise trap inside forest, at edge of first study quadrat.

Set up 13 sets of attractant logs for cerambycid project along marked (blue) route into study area: (12 sets of 3 each: koa, ohia & naio=Myoporum).

No.	Left or Right of track	Situation	Bait ("3" = koa, ohia & naio)
1	R	Elevated horizontal log-branch, 10m ex "road" before large Mal. trap	3
2	L	On old slender stump	3
3	L	On tree fern	3
4	overhead	Hanging on dead ?ohia	3
5	R	on fallen small koa	3
6	R	on large horizontal log & roots across track	3
7	L	Tree fern	3
	(50 m or more gap; then small Malaise trap; then first orange ribbons)		
8	L	Slender tree, left of track	3
9	R	Hanging from leaning <u>Cheirodendron</u>	3
10	R	On leaning <u>Cheirodendron</u>	3
11	L	Upper branch of log with blue and orange ribbons on log	3
12	R	On <u>Cheirodendron</u> with small koa tree	3
13	L	On horizontal log with blue & orange ribbons hanging	koa & naio only

Rearing: A large carton of naio (<u>Myoporum</u>) branches was sealed up for rearing adults, in garage at house in park.

<u>Maui I.</u>

On 27 November, search was made for cerambycid larvae in <u>Vaccinium</u> and <u>Styphelia</u> on the slope of Haleakala, just below Park boundary. Evidence of old, suspected, cerambycid borings were found in <u>Styphelia</u>. No records exist for these hosts on Maui. One carton each of trunks were set up for rearing adults and left in Haiku.

C-3

Communication letter to Park Superintendent on
Acacia psyllid infestation, Mauna Loa transect.

C.J. Davis

While on an I.B.P. field trip on the Mauna Loa Strip, 22 July 1970, we stopped at the Kipuka Kulalio portion of the I.B.P. transect at approximately 1645 meters.

An extremely heavy infestation of the Acacia psyllid, _Psylla uncatoides_ was observed on _Acacia koa_, the first record of this pest in Hawaii Volcanoes National Park. It was doing extensive damage to the terminal growth of koa and I considered it serious enough to warrant weekly observations.

I discussed this pest with your personnel and made arrangements for our Hawaii Resident Entomologist, Ernest Yoshioka, to make these observations. This has been accomplished and on a visit to this locality on 18 August, we were pleased to note almost complete recovery from this pest. Psyllid populations were low but what effect this residual population will have on new terminal growth remains to be seen.

Would it be possible for your staff to make periodic observations and report findings to our Survey Entomologist, Kenneth Kawamura, State Department of Agriculture, Entomology Branch, P.O. Box 5425, Honolulu, Hawaii 96814?

It is possible that natural enemies of _P. uncatoides_ are holding it in check on the Mauna Loa Strip and may be responsible for the koa recovery noted. We have some evidence of this but I do not have a complete report from Ernest Yoshioka of my Hilo staff.

The _Acacia_ psyllid was first discovered on Oahu in 1966 and has since spread to Kauai, Maui and Hawaii. It was first observed on the Big Island at Kawaihae Uka, Kohala District on _Acacia koaia_, a rare tree, in March of this year.

For further information see report of Beardsley (C-5).

dated September 1, 1970.

W. Gagné

Proposed sampling program for IBP transects

The purposes of the sampling techniques outlined below are firstly, some of those in conjunction with Objective 1 (Speciation) for (a) estimates of the numbers and variation in numbers of each species at all defined locations, leading to a dynamic assessment of speciating and non-speciating organisms, such that possible contrasts in seasonal or other types of population size variation may be detected and (b) the study of competition for discerning elements of competition between species. For Objective 2 (Stability and fragility) some of these would be (a) a quantitative assessment of population sizes and (b) for the assignment of the structural position of some Heteroptera within each ecosystem along the transects. In the course of achieving these objectives the raw data for Objective 3 (Biomathematical relationships) would be provided.

It is proposed that the sampling procedure for the Kilauea koa forest to be part of an integrated sampling program on the 2 ecological dominants (ohia and koa) in the Mauna Loa and Mauna Kea transects. Sampling stations will be established in adjacent ohia and koa stands located on lava substrates of different ages such that there will be a cross-section of communities from those newly established on young lava to apparent climax communities. Approximately 5 sites for each species will be selected corresponding roughly to establishment on new substrate, transitional (trees approximately 5 years old and 1 m or higher), canopy closure, young forest and climax forest.

The arthropod fauna will be sampled by spraying the foliage with insecticide and catching the falling arthropods in cloth funnels suspended beneath the trees. A pyrethrin spray, synergized with piperonyl butoxide will be used to provide very fast knockdown with minimal residual effect. The spray will be applied with a gasoline powered, hydraulic sprayer to thoroughly wet the foliage.

The shape and size of the sampling funnels will vary according to the size of the trees to be sampled. In the transitional stages where the branches of the trees are near the ground, a flat sheet approximately $3m^2$ will be used. Ropes will be passed through the perimeter of the sheet and fastened to the trunks. In the closed canopy and young forest stages where the lower branches are several meters above the ground, a funnel $3m^2$ x 1m deep will be fastened to the trunks of 4 trees selected such that roughly a fourth of the crown of each tree will extend over the funnel. Thus each funnel will sample 4 quarters and a complete sample in each stand of these 2 species will consist of approximately 4 funnels in each stand such that a fourth of each of 16 trees respectively, will be sampled. In the oldest stages (climax forest) the funnels used will be $6m^2$ and about 2m deep. These will be attached between 6 trees such that 3 will be on each of 2 sides to provide the same relative sample as that taken in the younger stands.

Sampling will be carried out once a month at each site throughout the year and the same tree will never be sampled more than once a year.

The spray will be applied at dawn before substantial insect activity is underway. Large plant fragments and debris dislodged will be removed before the catch is emptied into covered plastic trays for preliminary sorting at the lab. During the first phase of sorting, specimens to be dry mounted, pinned and etc. for identification will be immediately removed and the rest of the sample will be preserved in IsO-Carnoy such that a record of the chromosome content of the sample will be obtained for studies such as the genetic polymorphism and population genetics of the species obtained, to "kill two birds with one stone" so to speak. As a reference collection is assembled, the need to specially treat unknown species will decrease.

Estimates of sampling error will periodically be made by plastic packaging samples in the field and fumigating them in the lab to provide, by extrapolation some idea of the amount of the sample missed and the type of organisms being overlooked because of the sessile habits or whatever.

Seedling and root sprouting koa and ohia too small to be sampled effectively by the spray technique outlined above, will be examined visually. Those individuals touching a line 100 m long across the sampling area will be so examined and every 10th individual will be uprooted for lab examination of internal root and stem borers, and etc.

To obtain comparative estimates of the insect activity within and into the Kilauea koa stand, Malaise traps will be erected at the edges of the virgin and logged forests and within each.

Exclusion cages will be assembled in each of the communities. In this way the insect community can be removed manually or with the nonresidual spray and the dominant phytophages and their predators and parasites can be introduced into the cages in various combinations to gain some numerical assessment of the population dynamics of the phytophages alone and in combination with their suspected controlling agent(s) - for example, the introduced koa psyllid and its suspected mirid predator, a Psallus species, together and separately.

Wherever possible the sampling stations will be established in conjunction with a weather station to maintain correlation with the climatic parameters. Also for comparative purposes, initially a set of koa and ohia sampling stations will be established at roughly the same altitude on the transect on the windward face. It is anticipated that as the program expands and more help is budgeted that a number of such sampling stations will be similarly established throughout both the Mauna Loa and Mauna Kea transects, but with close attention being paid to the physical limits of the operation of a great number of sampling stations. Perhaps, initially, it will be sufficient to set up sampling stations at elevations comparable to the Kilauea koa forest on both transects.

To this sampling proposal I am attaching a preliminary list of the Heteroptera (true bugs) whic occur or which there is good reason for expecting them to occur in the two Big Island transects. I would have liked to have compiled a list of all the insects in these two transects but the task is too immense for one person alone to attempt. It is hoped that each of the entomological investigators will compile such a list for his respective group so that we have at least the rudiments of the fauna that can be expected to be encountered in the course of this sampling program.

List of Insects Occurring in Big Island Transects

TAXON	TRANSECT Mauna Kea	Mauna Loa	BIOLOGY & COMMENTS
HETEROPTERA			
Plataspidae			
*Coptosoma xanthogramma	X	X	Phyt.[1] Legumes: Canvalia, Strongylodon, Erythrina
Cynidae			
*Geotomus pygmaeus	X	X	Terrestrial, among grasses
*Rhytidoporus indentatus	X	X	" "
Pentatomidae			
Oechalia acuta	(X)[2]	X	Pred.[3] Lepidoptera larvae on many hosts.
O. bryani	X	X	ditto,espc. on Sophora and Metrosideros
O. ferruginea		X	ditto,up to 4000'
O. grisea	X	X	" , " ,Metrosideros
O. hirtipes		X	" ,No host plant known.
O. koanohi		X	As for acuta. Grass feeding
O. pacifica	X	X	" " " . Myoporum, Dodonea
Scutelleridae			
Coleotichus blackburniae	X	X	Phyt. Acacia koa
Rhopalidae			
Ithamar hawaiiensis		X	Phyt. Chenopodium, Sida.
Liorhyssus hyalinus	X	X	Phyt. No hosts recorded
Lygaeidae			
*Geocoris pallens	X	X	Pred. on terrestrial insects
Metrarga nuda	X		Phyt. Seeds of Freycinetia
Neseis (Trachynysius) o. ochraisis	(X)	X	Phyt. Seeds of Sophora & Pelea
N. (T.) o. maculiceps		X	Phyt. Seeds of Sophora
N. (T.) f. fasciatus	X	X	Phyt. Seeds of Rubiaceae
N. (T.) hiloensis	X	X	Phyt. Seeds of Pipturus
N. (T.) nitidus comitans	X	X	Phyt. Seeds of Pipturus
N. (T.) n. pipturi	(X)	X	Phyt. Seeds of Pipturus
N. (T.) saudersianus		X	Phyt. Seeds of Urera,Sapindus
N. (T.) whitei		X	Phyt. Seeds of ?
Nesocymus calvus		X	Phyt. Seeds of Carex
Nesomartis psammophila	(X)	(X)	Phyt. Seeds of Eragrostis
Nysius beardsleyi		X	Phyt. Seeds of Dodonea
N. blackburni	X	X	Phyt. Seeds of Amaranthus, Sophora,Dubautia,Clermontia
N. communis	X	X	Phyt. Seeds of numerous hos[illegible]
N. deletulus	X		Phyt. Seeds of Dubautia scabra

(continued, next page)

TAXON	TRANSECT Mauna Kea	TRANSECT Mauna Loa	BIOLOGY & COMMENTS
N. kinbergi	(X)	X	Phyt. Seeds of Erigeron
N. mauiensis		X	Phyt. Seeds of ?
N. montivagus		X	Phyt. Seeds of ?
N. lichenicola		X	Phyt. Seeds of Eragrostis
N. longicollis		X	Phyt. Seeds of ?
N. delectus	X		Phyt. Seeds of many hosts.
N coenosulus	X	(X)	Phyt. Seeds of Styphelia
N. rubescens		X	Phyt. Seeds of ?
N. terrestris	(X)	(X)	Phyt. Seeds of Argyroxiphium, Sida, Wikstroemia, Hibiscus, Dubautia, Styphelia, Sophora, Portulaca
Oceanides bryani	X	X	Phyt. Seeds of Euphorbia, Psychotria
O. nimbatus	(X)	X	Phyt. Seeds of Vaccinium (and others)
O. nubicola		X	Phyt. Seeds of Myoporum
O. pteridicola	X	X	Phyt. Seeds of Metrosideros
O. vulcan		X	Phyt. Seeds of ?
*Pachybrachius nigriceps	X	X	Phyt. Seeds of Lythrum
*P. pacificus	X	X	Phyt. Seeds of grasses
Tingidae			
*Teleonemia scupulosa	X	X	Phyt. Sap of Lantana camara
*T. vanduzeei	X	X	Phyt. Sap of Lantana camara
Reduviidae			
*Empiocoris rubromaculatus	(X)	X	Pred. on many arthropods
E. whitei	(X)	X	" "
Nesidiolestes insularis		X	" "
*Ploiaria insolida	(X)	X	" "
*Zelus renardi	(X)	X	" "
Nabidae			
Nabis blackburni	(X)	X	" "
*N. capsiformis	X	X	" "
N. curtipennis	X		" "
N. innotatus		X	" "
N. kahavalu		X	" "
N. kaonohuila		X	" "
N. koelensis		X	" "
N. lusciosus		X	" "
N. oscillans		X	" "
N. pele		X	" "
N. subrufus	X	X	" "
N. tarai	(X)	X	" "
N. vulcanicola		X	" "
Anthocoridae			
Lasiochilus denigratus	X	X	Pred. on many arthropods; on Antidesma, Cibotium, Coprosma

TAXON	TRANSECT Mauna Kea	Mauna Loa	BIOLOGY & COMMENTS
Lasiochilus montivagus		X	Pred. on many arthropods
Orius persequens	X	X	" " ; hemimetabolous insects on many plant
Physopleurella mundula	X	X	Pred. on many arthropods
Xylocoris sp.	X		" in Chenopodium
Miridae			
*Fulvius variegatus	(X)	(X)	" "
*Hyalopeplus pellucidus	X	X	Phyt. many plants (Dodonea)
Kamehameha lunalilo	X	X	Pred.? predominately on ferns
Koanoa hawaiiensis	X	X	Pred. on many arhtropods, some under bark
Nesidiorchestes n. spp.	(X)	X	Pred.? predominately in leaf litter
Nesiomiris hawaiiensis	X	X	Phyt. sap of Ilex anomala
N. n. spp.	X	X	Phyt. sap of native Araliaceae
Orthotylus spp.	X	X	Phyt. sap of many native plant. particularly Rubiaceae, Pipturus, Sophora
Psallus iolani		X	(?Gen arthropod predator, host specific)
P. kanakanus		X	" "
P. kassandra		X	" "
P. kirkaldyi		X	" "
Pseudoclerada kilaueae		X	(?Gen arthropod predator, mossy trunks of native plants
P. morai	(X)	(X)	" "
*Rhinocloa forticornis	X	X	Gen. arthropod predator on native & introduced plants
Sarona adonias	X	X	Phyt. sap of Metrosideros
S. n. spp.	X	X	Phyt. sap of Pipturus, Pelea, Myoporum
Sulamita dryas		X	Phyt. sap of ?
S. lunalilo		X	Phyt. sap of Freycinetia, Fagara
S. n. spp.	X	X	Phyt. sap of sev. other native plants
Trigonotylus (hawaiiensis)	X	X	Phyt. sap of native grasses
Veliidae			
*Microvelia vagans	X	X	Pred. arthropods on surface of pools and streams
Hebridae			
*Merragata hebroides	X	X	" "
Saldidae			
Saldula oahuensis	(X)	X	Pred. on arthropods along strean
Saldula sp.	X	X	Pred. on arthropods on mossy tree trunks in rain forest
Corixidae			
*Trichocorixa reticulata	X	X	Phyt. on aquatic algae

* Introduced or probably so.
1 Phytophagous.
2 Bracketed material indicates probability of being so indicated.
3 Predaceous.

C-5

Progress report on effects of sap-sucking Homoptera on Hawaiian ecosystems.

J.W. Beardsley

Since work on this research topic was initiated during June 1970, we have concentrated on the ecology and population dynamics of Homoptera which feed on _Acacia koa_, particularly the _Acacia_ psyllid, _Psylla uncatoides_ (Ferris and Klyver). Most of thework was conducted on the Mauna Loa transect in Hawaii Volcanoes National Park. Some supplementary observations were made in the Koolau Mountains on Oahu.

Psylla uncatoides is a recent accidental introduction into the Hawaiian Islands. It was first discovered on Oahu in 1966 and on Hawaii in Mar.,1970. Very heavy populations have been observed on _Acacia_ species, including the endemic _A. koa_. The recent advent of this insect in Hawaii and its potential for developing large and damaging populations appear to make this species an ideal subject for a study of the impact of an introduced organism on an important element of the endemic biota.

Three sampling sites were selected in the Koa-savannah and mountain parkland sections of the transect, at altitudes of 4,300 ft., 5,300 ft. and 6,600 ft. respectively. The upper site is at the upper limit of koa growth in this region. Samples of koa terminals were taken at each sample site at intervals of approximately six weeks, beginning on July 22. As the koa psyllid breeds only on young phyllodes and juvenile foliage, the outer four inches of twigs with young leaves was selected as the sampling unit. Ten randomly selected terminals were bagged and cut at each sample site, and brought to Honolulu, where all stages of psyllids, as well as other insects, were counted.

Results

At the time of the initial survey field trip on July 22, koa psyllid populations were extremely high at all three sites. Although only three samples were actually collected and counted at that time,these averaged about 43 adults, 227 nymphs and 419 eggs per sample. These populations appeared to represent an initial population explosion of the psyllid following its invasion of the Island of Hawaii. By August 26, when the first complete sampling was made, populations had declined drastically. At this time virtually all koa twigs exhibited a dieback of the terminal three to six inches, which is believed to have been caused by psyllid feeding during the initial outbreak. Two subsequent samples taken on October 7 and November 16 respectively, showed a moderate to slight resurgence of psyllid populations on new growth put forth following the initial dieback. It is of interest that this resurgence of psyllid populations was greatest at the highest site (6,600 feet) and least at the lowest site (4,300 feet). To date these resurgent populations have remained at a relatively low level, approximately 1/5 to 1/30 of the outbreak levels observed in July.

No evidence of insect parasites of the psyllid was found. A number of predator species were found feeding on psyllid eggs and nymphs. These included larvae of several introduced and endemic species of Neuroptera, and larvae and adults of one introduced coccinellid beetle. These species have been identified, but we are not yet able to evaluate their effectiveness.

T. Nishida
F.H. Haramoto
L. Nakahara

Progress report on faunal research on *Metrosideros*.

Studies to date have been limited to working out sampling methods and to the selection of sampling sites so that the desired information on the fauna of *Metrosideros* could be obtained most efficiently and economically. Various extraction methods such as washing, beating, brushing, and flotation have been tried, but extraction by means of Tullgren funnels has proven most fruitful in sampling most of the arthropods that live on the aerial parts of *Metrosideros*. A battery of 30 Tullgren funnels was assembled and used to extract the arthropods from *Metrosideros* twig and bark samples collected on November 21-22, 1970 from six plots located at different elevations on the southeast slope of Mauna Loa on Hawaii.

A twig sample consisted of 10 terminal branches per tree and three such samples were taken from each plot. A bark sample consisted of about 200 gm of material scraped from the trunk per tree and three such samples were taken from each plot. Each sample was placed in a Tullgren funnel and allowed to dry under a 40-Watt electric bulb for four days. The bark and twig samples were collected from one variety of *Metrosideros*, *M. collina* var. *incanna*, from each of the six sampling sites on a transect 600, 1700, 3600, 3800, 4000, and 7000 feet above sea level on the southeast slope of Mauna Loa. Examination of some of the extracts of the Tullgren funnels has revealed that there exists a rich fauna of arhtropods on the aerial parts of *Metrosideros*. For example, from one of the bark samples obtained from a tree at 3700 ft. elevation 773 specimens of arthropods representing at least 30 different species were extracted. Among the most numerous of the arhtropods were mites of the suborder Cryptostigmata. Of the total arthropods, 631 of them were cryptostigmatic mites of the families Nanhermanniidae, Achipteriidae, Euphthiracaridae, Phthiracaridae, Galumnidae, Cerotizetidae, and Trhypochthoniidae. From the twig sample from the same tree , 138 specimens of arthropods were extracted and once again mites made up more than 50% of the fauna. Of particular interest was the presence of so many cryptostigmatic mites so high up in the tree. These mites are normally soil-inhabiting organisms.

Most of the species extracted from the bark and twig samples were not pests of *Metrosideros* but were species normally found in close association with lichens,mosses, and fungi. The more important phytophagous arthropods found feeding directly on *Metrosideros* were mealybugs, eriophyid mites, and gall-forming psyllids. Another interesting group of arthropods that occurred in large numbers was the predaceous mites and insects.

Progress report on soil and duff inhabiting arthropods and vertebrate parasites.

F.J. Radovsky

A. Soil and Duff

1. Field studies and collections

Field work was conducted on the island of Hawaii on 14-18 June (F.J. Radovsky and M.L. Goff), 21-22 July (F.J.R., IBP Orientation trip), and 19-22 October (M.L.G.), of 1970. A total of 87 samples were taken, principally on or near the Mauna Loa transect from 3280 to 8200 ft. (1000-2500 m) and the Mauna Kea transect from 460 to 9250 ft. (140-2820 m). Wherever possible, these were associated with transect zones, dominants in the vegetational community, and plants forming the duff samples taken. Most samples were duff or soft humus. When we begin sampling deeper zones and primarily mineral soils, it may be necessary to use flotation and/or agitation techniques, in addition to Berlese funnels, for recovery of arthropods.

Collections made from fumaroles have yielded mites and insects. Collembola were recovered from a sample for which an <u>in situ</u> temperature of 78°C was recorded with a mercury bulb thermometer. It is essential that we obtain equipment to provide accurate point source measurements of sample temperatures for future studies.

2. Processing and identification

All collected samples have been extracted in Berlese funnels. The funnels have smooth flat inner surfaces and drying was by equilibration with room atmosphere with moderate RH, rather than by a heat source. Both factors tend to increase the percentage of arthropod recovery. Arhtropods were sorted into general groups (Mesostigmata, Oribatei, Coleoptera, Collembola, other apterygotes, etc.). Oribatei, forming a major component of the fauna, have been forwarded to Dr. Sengbusch. Other Acarina are being mounted at the Bishop Museum. Preliminary sorting to family and in some cases to genus has been started.

Contacting other specialists was delayed because of the absence of Radovsky in September and October on overseas work, but this will be recommenced immediately.

B. Parasites of Vertebrates

1. Field studies and collections

Vertebrates were collected for parasite recovery on the 14-18 June and 19-22 October trips referred to above. Mammals collected were <u>Mus musculus</u> (11), <u>Rattus rattus</u> (7), <u>R. norvegicus</u> (9), <u>R. exulans</u> (15), and <u>Herpestes auropunctatus</u> (3). In addition to brushing for ectoparasites, a part of each series of hosts was washed individually in detergent solution; this technique yields fur mites, and other parasites when present, that are usually missed by brushing.

A permit has been obtained from the Division of Fish and Game to collect Hawaiian land birds, including small numbers of the 3 commonest endemic drepanids and the one endemic flycatcher. Collecting will be done in an area outside Volcanoes National Park. Dr. Berger loaned us approximately 15 specimens of endemic birds in liquid preservative. At least 3 species of feather mites and 1 species of nasal mites were obtained from them. Six bird nests just collected on Hawaii and Oahu within a few days of being vacated and 6 others that had been held for several weeks or months, including several of native birds, were processed in Berlese funnels and a number of parasites recovered.

2. Processing and identification

All of the collected parasites have been sorted and series mounted. These have been identified to family and the species from endemic birds to genus or species.

<u>Plan of next work</u> C-9(2)

Arthropod fauna of soil and duff; parasites of vertebrates

Qualitative and quantitative studies will be conducted on the arthropod faunal composition of soil and duff, in relation to substrate type, vegetational origin and association, age, altitude, proximity and microclimatic influence of volcanic activity, etc. While comparative data will be obtained from other islands and areas, the main emphasis will be on the established transects on the island of Hawaii. This will permit maximum utilization of data obtained by others in interpreting results and will provide information of most use to investigators working on other phases of the project, including synthesis of general conclusions. Because the habitat has received little attention in the past, considerable effort initially will be directed toward qualitative sampling and basic systematic studies. The collaboration of many specialists will be needed to carry out this primary phase. The overall objectives are to obtain knowledge of (1) species composition of arthropods associated with different soils and leaf litters in Hawaii; (2) succession of arthropods in soils of volcanic origin, relative to species requirements and effect of arthropods on the substrate; (3) extremes of temperature tolerance among arthropods colonizing substrates influenced by volcanic activity (fumaroles, etc.); (4) evolution of selected groups in the archipelago; (5) physical and biotic factors influencing habitat specificity; (6) respective roles of specificity and natural barriers in isolation and speciation. These objectives closely correlate with the 4 principal objectives of the Hawaii Subprogram.

The basis for the second part of this project, concerning parasites of vertebrates, was outlined in the original proposal (C-9). Arthropod parasites will be emphasized, and other parasites will be collected in conjunction with research projects of collaborating scientists (Gordon Wallace on <u>Toxoplasma</u>, J. Frankel on <u>Sarcocystis</u>, at present).

These 2 subjects are combined because they can be most conveniently administered as a single project and because combined field work is practical. Collection of vertebrates, removal of parasites, and preparing vertebrates for identification and permanent reference requires considerable effort in the field. Collection of soil and duff samples for Berlese extraction can be done in a relatively short time, even when it is essential that quantities be determined, precise collection data recorded, and physical parameters measured. Extraction of arthropods from nests can be carried out with the same techniques used on soil samples. Sorting and processing of arthropods from soil or from vertebrate hosts involves the same or similar methods. Some of the participating specialists, particularly for Acarina, work on both free-living and parasitic groups.

Report on IBP field trips to Hawaii. A.J. Berger

This report covers the two trips I have made on the IBP project since its funding last June. I took part in the general survey led by Mueller-Dombois on July 21-24, and with the smaller group on Nov. 20-22,1970.

The birds of Volcanoes National Park are relatively well known because of the work done there by Paul Baldwin, William Dunmire, and other park naturalists during the past 30 years. There have been some notable changes in numbers and species of birds between 1940 and 1970, but there have been few census studies published during the past decade. Some of the rarer species found in the 1940's apparently no longer occur in the Park.

As for the transects and study plots within Volcanoes Park, very few native birds are found as high as 8,000 feet. I saw three Hawaii Amakihi (Loxops virens) at 8,000 feet on July 22, 1970, but at that time of year, the birds very likely were merely moving through the area. Don Reeser and Patrick Crosland of the Park Service and Winston Banko of the Rare and Endangered Species Program reported that in the past, they had seen the Hawaiian Thrush at elevations between 7,000 and 9,000 feet on the trail to the summit of Mauna Loa. I neither saw nor heard any thrushes on July 22, 1970. Two introduced species of birds (Japanese White-eye and Red-billed Leiothrix) occur from below Park Headquarters (3,800 feet) to at least 7,500 feet elevation.

The prime habitat for native birds within the Volcanoes National Park is in the vicinity of Thurston Lava Tube and similar high-rain areas. The number of native birds drops off rapidly as soon as one passes through the transition area between the rain forest (e.g., at Thurston Lava Tube) and the summer dry area (e.g., the 1938 "hotspot" region). I saw only two species of native birds (Apapane and Amakihi) in that area on Nov. 22, 1970.

The Hawaii Amakihi has the widest range of any native bird species within the Park. I have found it at elevations from 8,000 feet downward to about 1,800 feet at the Naulu picnic area on the Chain of Craters Road.

Paul Baldwin did his Ph.D. thesis on the three most common drepanids (Apapane, Iiwi, and Amakihi) in Volcanoes National Park. Although it would, of course, be possible to do further work on these three species within the Park, there are far more challenging and important studies that should be made on the breeding biology and the ecological relationships of the endemic birds in areas outside of the Park, on Maui and on Kauai.

The Kilauea Forest Reserve (Bishop Estate Land) is one of the finest native forests I have seen on the Big Island, and, in my opinion, everything possible should be done to preserve it intact. Whether or not this proves to be possible, the area should be studied intensively, according to plans of Mueller-Dombois. The period from July to November is the poorest time of the year to study the endemic birds, especially with regards to obtaining fairly accurate census data. I intend, therefore, to devote considerable energy in this area with my Research Assistant during January through June.

Despite the fact that many endemic birds apparently are in the post-breeding, molting period during the general period from July to November, a large number of thrushes was singing in this forest on July 23 and on November 20, 1970. This forest undoubtedly supports as high a concentration of thrushes as any other area in Hawaii. Elepaio, Apapane, and Amakihi also are present in good numbers. Thus far I have seen two species of introduced birds in the Kilauea Forest Reserve: White-eye and Leiothrix, and I have found nests of both species there.

A surprising discovery on November 21, 1970, was the sighting of a single Cattle Egret along the Chain of Craters Road at an elevation of about 900 feet.

Field trips during the coming months should provide more precise information on population sizes within the study plots and undoubtedly will reveal the presence of other species of native birds.

Preliminary Status of Native Birds, Kilauea Koa Forest,[1]
Kau District, Island of Hawaii
(List compiled by Winston Banko, Biologist, Hawaii National Park, Oct.1970)

1. Hawaiian Hawk (Buteo solitarius)

   Found only on Island of Hawaii. Populations are apparently declining. Resident in Kilauea Koa Forest, but rare. Species listed as endangered by U.S. Department of Interior.

2. Hawaii Thrush (Phaeornis obscurus obscurus)

   Found only on Islnd of Hawaii where a widespread population exists. In Kilauea Koa Forest it is locally abundant in undisturbed areas, common to rare elsewhere.

3. Hawaii Elepaio (Chasiempis sandwichensis sandwichensis)

   Found only on Island of Hawaii where populations are widespread. In Kilauea Koa Forest this race is locally abundant in undisturbed areas, common to rare elsewhere.

4. Hawaii O-o (Moho nobilis)

   Formerly found only Island of Hawaii. Now thought extinct. Once presumably resident in Kilauea Koa Forest.

5. Hawaii Amakihi (Loxops virens virens)

   Found only on Island of Hawaii where populations are widespread. In Kilauea Koa Forest, Hawaii Amakihis are locally abundant in some areas, common to rare elsewhere.

6. Hawaii Creeper (Loxops maculata mana)

   Found on Island of Hawaii where status is unclear. Resident in Kilauea Koa Forest. This bird is a potential candidate for U.S.D.I.'s list of endangered species.

7. Hawaii Akepa (Loxops coccinea coccinea)

   Found only on Island of Hawaii. Populations apparently declining. Resident in Kilauea Koa Forest. Hawaii Akepa is included in proposed revision of U.S.D.I.'s list of endangered species.

8. Hawaii Akialoa (Hemignathus obscurus obscurus)

   Formerly found only on the Island of Hawaii. Now thought extinct. Once resident in Kilauea Koa Forest.

9. Akiopolaau (Hemignathus wilsoni)

   Found only on the Island of Hawaii. Once abundant and widespread. Resident in Kilauea Koa Forest, but rare. Listed by U.S.D.I. as an endangered species.

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10. Ou (Psittirostra psittacea)

Once common on all the major islands. Now found rarely only on Kauai and Hawaii. Formerly in Kilauea Koa Forest where current status is uncertain. Listed by U.S.D.I. as an endangered species.

11. Greater Koa finch (Psittirostra palmeri)

Formerly found only on the Island of Hawaii. Now thought extinct. Once resident in Kilauea Koa Forest.

12. Apapane (Himatione sanguinea sanguinea)

Formerly very abundant on all major islands. Now absent from Lanai and rare on Molokai. The most numerous bird in Kilauea Koa Forest today.

13. Iiwi (Vestiaria coccinea)

Formerly found on all major islands, now apparently extinct on Molokai and Lanai. Widespread though not abundant resident of Kilauea Koa Forest.

14. Mamo (Drepanis pacifica)

Formerly found only on Island of Hawaii. Now thought extinct. Once presumably resident in Kilauea Koa Forest.

Biosystematics of Hawaiian Diptera project, Progress Report and Plan of Work

M. D. Delfinado
D. E. Hardy

Progress Report:

The results of the preliminary survey of the insect communities on the Wailuku River, Hawaii, indicate that 3 aquatic dipterous genera (Telmatogeton, Chironomidae; Procanace, Canaceidae; Neoscatella, Ephydridae) will provide excellent groups of animals for testing the hypotheses put forward in Hawaii IBP objectives 1-4. These groups are the major components in rapids and waterfalls in Hawaiian streams. We have sampled the major streams on Hawaii, Maui, Oahu, and Kauai and have obtained considerable biological data on these flies. In other parts of the world these are found almost exclusively in the intertidal zone of rocky seacoasts and estuaries.

The Telmatogeton group is a pleisiomorph (primitive) aggregate with unknown relationships but the immatures indicate relationship with the Diamesinae. It has its main center in the Pacific, but is world-wide in distribution and comprises 5 genera and 30 species. Two genera are present in Hawaii with 5 species confined to rapid mountain streams and 3 in intertidal zone. Interestingly, Brundin (1966) advanced a theory that chironomid evolution started in cool mountain streams, and that the adaptations of the ancestral forms (such as, the Telmatogeton group found in Hawaii) to strong current was a prerequisite for the entrance of at least two groups into another major adaptive zone, i.e., the marine environment. It is possible though that the situation, based on morphological and ecological evidences, is reversed in Hawaii.

Procanace, or beach flies, have many aspects of the distribution and ecology which parallel those of those of the Telmatogeton. About 50 species are known around the world with the greatest development in the Pacific. Eleven freshwater and one estuary species are found in Hawaii. Both groups (Telmatogeton and Procanace) show adaptations of behavior rather than structure. They are numerous in swift current where they have an ample food and oxygen supply. They have avoided the dangers of shifting bottom, hence, the selection of stable substrata. Drought or low water has catastrophic effect on the immatures because it causes decomposition of algae which may produce a lowering of the oxygen concentration.

Of the dipterous families, the Ephydridae, shore flies or brine flies, are most abundant. There were not only more ephydrid species, but greater numbers of individuals than in the other groups. The ephydrids are widely distributed; they inhabit a wide range of aquatic and semi-aquatic habitats; and they are unusually tolerant of adverse physical and chemical conditions.

We are convinced that the Hawaiian chironomid midges and beach or shore flies will provide excellent groups for evolutionary studies because of their diversity and marked ability to survive in small niches over prolonged environmental stress, and they should be studied within the framework of the IBP.

Plan of Work:

The plan of work for next year will be a continuation of the ecological studies of the Diptera with emphasis upon the flies which develop in soil and litter at Transects 1 & 2 on Mauna Loa (Memo - December 20, 1971); and cytological studies of the endemic species of Telmatogeton (Chironomidae) to attempt to trace the origin and evolutionary development of the freshwater Hawaiian species. We also plan to do further investigations of other groups of native flies which may be of use in evolutionary studies.

Personnel

M. D. Delfinado - Department of Entomology
D. E. Hardy - Department of Entomology
H. L. Carson - Department of Genetics
L. Newman - Department of Biology, Portland State College
(1) Graduate Assistant in Entomology

Study Site

Transect Profiles 1 & 2, Mauna Loa.

Ecological Studies

Our preliminary investigations have made it obvious that many of the acalyptrate, and other flies go through their immature stages in the litter and soil. Except for studies of Drosophilidae breeding in rotting leaves, stems of fruits, etc., of certain native plants by Dr. W. B. Heed, no studies of the biology and ecology of the flies living in this habitat have been made in Hawaii, and at present it is impossible to associate immature stages with the adults or to make species or group identifications. The extraction technics by Berlese-Tullgren funnels now being used for sampling soil and litter inhabiting arthropods and the pit trap technics provide little information on the flies. Diptera larvae and pupae dessicate very rapidly and will not pass through the extractors; the only satisfactory method of recovery is by handsorting and by rearing.

We have adopted the Heed (1968) technic for rearing drosophilids from litter samples as described in our memo of December 20, 1971. Earlier samples have been collected at Kipuka Puaulu (segment 8) and Kilauea Forest (segment 11) on Transect 2, and for comparative purposes, further samples were collected in Olaa Forest and Kipuka 4140 on Saddle Road. It is planned that the extensive survey of the soil and litter larvae with greater emphasis on the flies will be made at different segments on Transects 1 & 2.

A half-time graduate assistant will be needed to help with the field sampling, to service the emergence cans, do sorting and help with the identification of species.

Evolutionary Studies

A. Preliminary cytological studies made by Dr. H. L. Carson and assistants on *Telmatogeton* larvae from Hawaii revealed that these have extraordinarily large and favorable salivary gland chromosomes. Other preliminary orcein smears were made on specimens collected in various streams on Hawaii, Oahu, and Kauai and the preliminary results are most exciting. The larvae can be readily obtained and it is possible that technics can be worked out so they can be reared in the laboratory. These flies should be ideal for genetic studies; and, with data provided by comparison of the chromosomes, behavior, and biology, we should be able to determine the origin of the freshwater species and trace the evolution of the Hawaiian species from the marine habitat. It is planned that Dr. Lester J. Newman, Portland State College, will be brought to Hawaii to spend approximately 6 months studying the chromosome variations and evolutionary development of the Hawaiian *Telmatogeton*. Dr. Newman has had considerable experience in cytogenetics of freshwater Diptera (Simuliidae) and should be able to make very important contributions to our understanding of evolutionary processes.

B. A most unusual situation has recently been discovered regarding a complex of agromyzid leaf miners which infest the leaves of an assortment of native plants. Dr. O. H. Swezey, during his lifetime of work on insects attacking native trees in Hawaii (1954, Forest Entomology in Hawaii), recorded finding agromyzid leaf miners attacking eight different genera of native plants. Because of the very high parasitism rate, however, he was never able to rear any adults. We have since been able to obtain adults from most of the hosts recorded by Swezey and have accumulated a large series of specimens by various collecting technics (including sweeping and Malaise Trap catches in the Kilauea forest, etc.). These are *Liriomyza* and according to Dr. K. Spencer, London (the world authority on Agromyzidae), all of our specimens fit the taxonomic concept of *L. langei* Frick, from western America. Yet the populations we rear from various hosts and obtain from various island habitats show great variations in color markings and size. Over the world, members of this genus are notoriously host specific and if they follow the usual pattern of speciation we should have a complex of species associated with our native plants. It is apparent that the ancestor of these populations reached Hawaii from the West Coast rather recently (geologically) and we are witnessing the beginning of speciation. This is the only known example of this phenomenon and our situation offers unusual opportunities for studying changes leading to species differences. Dr. Spencer has indicated, "It looks to me very much as though some complex speciation may have taken place from an original population of *langei* which reached Hawaii from either North or South America early in the island's history."

We need careful biological data on these populations before a better understanding can be had.

We will continue to gather data on these flies and will solicit the help of all IBP investigators to be on the outlook for mined leaves. We hope a way will be worked out to bring Dr. Spencer here to assist us with this study.

Significance and Relation to Other Projects

These studies will augment the work we are doing on the systematics of Hawaiian Diptera. Volume 13, dealing with the acalyptrate flies other than Drosophilidae is nearly completed, except for the illustrations and we are now working on volume 14 which treats the calyptrate flies. This will complete the volumes dealing with the adult flies and these works will provide the needed background information for ecological, evolutionary or other studies involving flies (the Evolution and Genetics of Hawaiian Drosophilidae project was made possible by the publication of volume 12 of the "Insects of Hawaii" which treated this family).

The Diptera are closely associated with native plants for breeding, feeding, resting, courtship and mating, etc., and many of them are no doubt essential for pollination. Some are borers in leaves and stems, many are scavengers, and many are predacious upon other animals in the habitat. Two of the major groups of native Hawaiian Diptera, the Dolichopodidae (presently 225 known species and estimated 400+) and the muscid genus Lispocephala (estimated 100 spp.) are predators. They feed upon a wide assortment of arthropods and obviously play an important part in the environment. Our litter-soil and other substrate studies should provide interaction data which will be directly applicable to other studies of the invertebrates which are being carried out.

The native flies serve as an important food source of many of the native birds and a knowledge of this fauna will be useful to the ornithological studies.

Progress report on the ecology of Hawaiian Sciaridae.

Three Malaise traps have been set up in the study sites on Hawaii, two in the Kilauea Forest Reserve and one at the weather station near the Mauna Loa Strip Road. Trap 1 was set up October 26, 1970, on the logging road at the edge of the Kilauea study site and was removed March 21, 1971. Trap 2 was set up December 7, 1970, near the beginning of Plot 1 in the Kilauea Forest Reserve study site. Trap 3 was set up January 18, 1971, near the weather station on the Mauna Loa Strip Road study site. Traps 2 and 3 will be removed at the end of January, 1972. All of these traps are at the same elevation and were initially sampled at weekly intervals; ater July 5, 1971, they were sampled on alternate weeks only.

The Malaise traps have been so productive in their yield of Sciaridae that it has been impossible to identify all of the species collected with the present technical assistance available. This resulted in the decision to sample on alternate weeks only and terminate the two remaining sampling stations after obtaining a one year sample from each site.

Based on the material processed to date Sciaridae form an unexpectantly large percentage of the arthropod fauna taken in the traps. This has not been the case in Malaise trap samples taken on the other islands, in New Guinea or in North America. Of the few collections completely analyzed, Sciaridae represent from 27% to 86% of all arthropods collected (in numbers of specimens). During the rainy season environmental conditions seem to be extremely favorable resulting in fantastic population explosions of certain species, i. e. Ctenosciara hawaiiensis (Hardy), Spathobdella setigera Hardy and Bradysia new species # 5.

Comparison of the catches of the two traps in the Kilauea Forest Reserve (Table 1) shows that with minor exceptions, both traps collected the same species. The three species usually collected, in order of their abundance, were Bradysia # 5, Sciara hoyti Hardy and Ctenosciara hawaiiensis (Hardy). The other four species listed in Table 1 were rare. Generally the collections of the three common species were higher in Trap 2.(Fig Comparison of the results obtained to date would indicate that, for general survey purposes, one or two sample sites would be sufficient. Sticky traps will probably be used to sample at the major relevés on the transects being sampled by other investigators.

Much more striking differences, both in magnitude of population fluctuations and species diversity, are found between the Kilauea Forest Reserve and the Mauna Loa study sites (Table 2, Fig. 2). Seven species species were collected in Kilauea Forest Reserve versus 11 at the Mauna Loa Strip Road site. The greater diversity of species at the Mauna Loa site could probably be explained by the greater plant diversity. Other investigators, except the Drosophila investigators, have found similar differences in species diversity between the two sites. The four most common species, in order of their abundance, were Spathobdella setigera, Ctenosciara hawaiiensis, Bradysia # 5 and Sciara hoyti.

Ctenosciara hawaiiensis is the only species which has been identified from all the collections; it is the only species which a technician can easily recognize. This species was approximately ten times more abundant at the Mauna Loa site. This difference can possibly be explained by the apparently greater volume of Koa on the ground at the Mauna Loa site. Ctenosciara hawaiiensis has frequently been reared from rotting Koa, plus from Metrosideros, Freycinetia and several other rotting woods.

The population fluctuations of Ctenosciara hawaiiensis seem to be closely correlated to rainfall (Fig. 2). The peak population of this species (February 22) occurred four weeks after the highest weekly rainfall (February 1). This corresponds roughly with the generation time of this species in the laboratory (see below). The other peaks of population size also are correlated to previous highs in weekly rainfall totals.

The ecological aspects of this study were stressed during the second year of this program in order to fit in better with the overall goals of the Island Ecosystems IRP. The third year will be devoted to surveys and ecological studies along the transects and initiation of studies of spermatogenesis.

Collaboration with other investigators includes identification of Sciaridae collected by Gagne, Gressitt, Howarth and Radovsky. Dr. G. E. Baker has identified some of the fungi associated with Sciaridae. Mr. W. Steiner has agreed to do electrophoretic analysis on selected species.

Two of the species mentioned above have been reared in the laboratory. Sciara hoyti is fairly easy to rear and has now been in culture for 12 generations. Each generation (from oviposition to adult emergence) takes about 30-31 days (range 26-36) at a constant temperature of 20°c. Ctenosciara hawaiiensis is more difficult to maintain in culture. Each generation takes about 23-34 days. Twelve other Hawaiian species have been reared in the laboratory, but could not be maintained because of shortage of technical assistance.

A report on the biology and ecology of Ctenosciara hawaiiensis including descriptions of the immature stages and spermatogenesis is being prepared as well as descriptions of new species of Sciaridac collected for this study. Other publications in progress include ecological studies of Sciara hoyti, Spathobdella setigera and Bradysia new species # 5. The first two publications will probably be submitted during the spring of 1972

Computerization of data will begin during the spring of 1972. A system for input and retrieval of collection and ecological data is being studied with collaboration from entomologists and statisticians on the mainland U. S. and Dr. Mi of our subprogram.

The only significant changes in the budget include the addition of another technician to process the tremendous mass of material being collected by myself and others. The camera is requested for photographing various parts of sciarids for descriptions of new species involved in the study. This method would be much less expensive and less time consuming than hiring and training an illustrator.

Table 1. Species of Sciaridae (Diptera) Collected in Malaise Traps in the Kilauea Forest Reserve and Their Relative Abundance.

	Trap 1		Trap 2	
Species	Presence	Abundance[1]	Presence	Abundance[1]
1. hoyti	+	53	+	128
2. hawaiiensis	+	13	+	108
3. prominens	+	1	+	7
4. setigera	-[2]	0	-	0
5. Bradysia #5	+	125	+	367
6. magnisensoria	-[2]	0	-	0
7. Bradysia #7	-	0	+	2

[1] Total number of specimens collected in a 6-week period.

[2] One specimen of each species was collected during an earlier sampling period.

Table 2. Comparison of Species Collected in Malaise Traps in the Kilauea Forest Reserve and Mauna Loa Strip Road Study Sites.

Species	Trap 2 (KFR) Presence	Trap 2 (KFR) Abundance[1]	Trap 3 (MLSR) Presence	Trap 3 (MLSR) Abundance[2]
1. *hoyti*	+	128	+	94
2. *hawaiiensis*	+	108	+	608
3. *prominens*	+	7	+	1
4. *setigera*	-	0	+	1,485
5. *Bradysia* #5	+	367	+	112
6. *magnisensoria*	-	0	-	0
7. *Bradysia* #7	+	2	-	0
8. *Lycoriella* #9	-	0	+	14
9. *Bradysia* #10	-	0	+	4
10. *Bradysia* #11	-	0	+	9
11. *Bradysia* #12	-	0	+	1
12. Unplaced	-	0	+	1
13. Unplaced	-	0	+	2

[1] Total number of specimens collected during a 6-week period.

[2] Total number of specimens collected during a 3-week period.

Fig. 1. Comparison of weekly Malaise trap collections at two sites in Kilauea Forest Reserve.

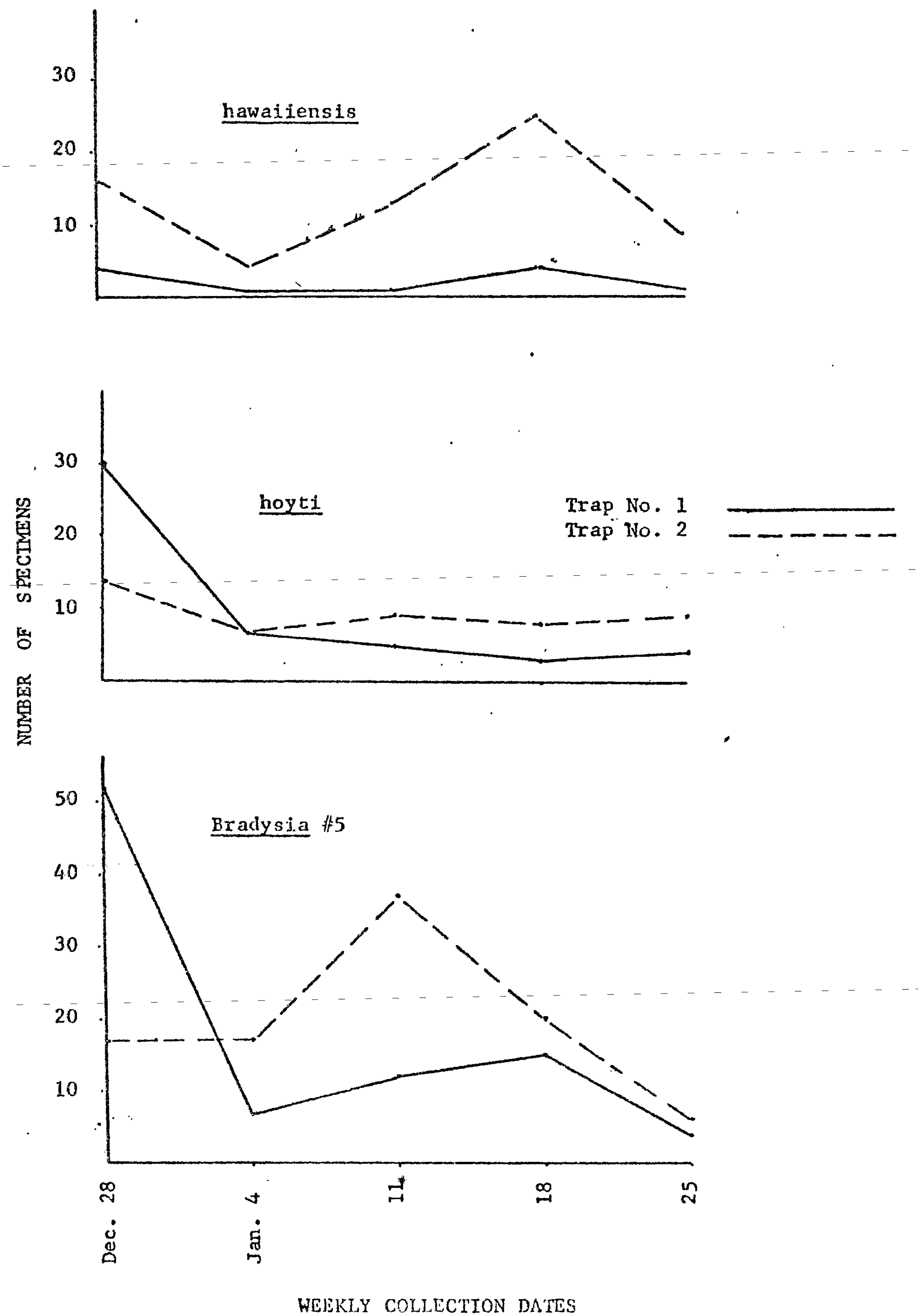
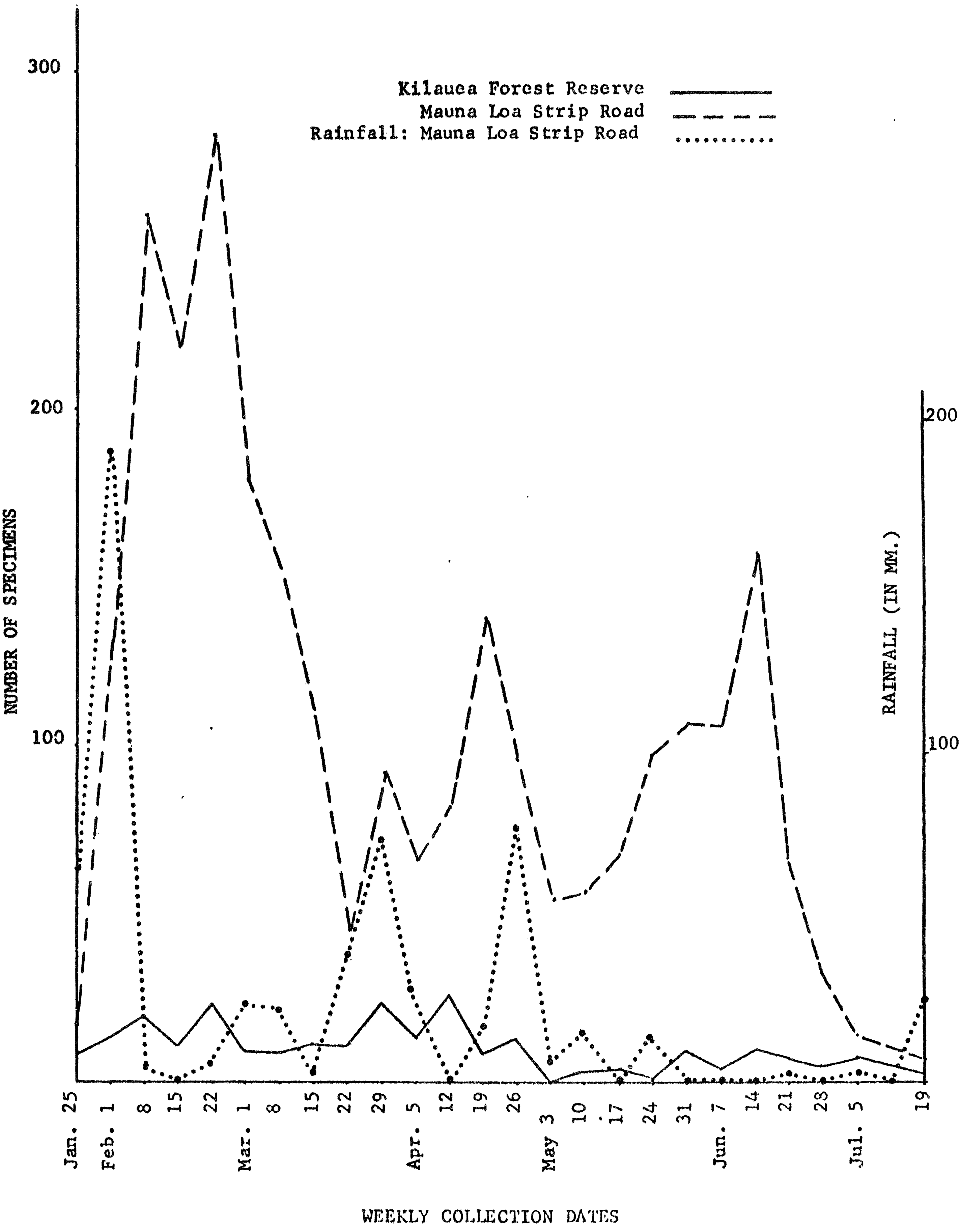


Fig. 2. Comparison of C. hawaiiensis collected in Malaise traps at Kilauea Forest Reserve (Trap 2) and Mauna Loa Strip Road (Trap 3) correlated with rainfall data from Mauna Loa Strip Road.



Interim report on Cerambycid-beetle project J.L. Gressitt

Biology: Data are being accumulated on several species in the study areas. Plagithmysus varians, on koa, has been found in greatest abundance, on fallen koa trees, or major branches of living trees. These were mostly found in Kipuka Ki and Kipuka Puaulu. On a large newly fallen branch in former, in mid-October, about 400 individuals were found, mating and ovipositing. Over a period of a few weeks nearly 100 of these were marked by a numbering code system. About 20 of these were recovered later, a few of them more than once, but by mid-November the population was quite low, and by mid-December still lower. The adults rest on adjacent vegetation and weeds at night and do not become active in morning until the sun strikes them or with considerable temperature rise, often just before mid-morning. Mating is repeated, with often ♂ half riding on back of ♀ while latter oviposits in cracks in bark, laying a number of eggs. One oviposition takes about 20 seconds. Life-cycle is probably about 6 months, longer in winter and perhaps shorter in summer. Adult life-span is apparently less than 2 months. Beetles were not found sleeping on main branches (see Predation). Mating and oviposition was achieved in cages, and also for a new species from Sapindus (see Davis report).

Place in the ecosystem: The above species, and many others, attack injured trees and branches, or unhealthy portions, as well as those felled by storms, rot and termite damage. Thus, many of the species are scavengers. Other species, like those in Myoporum, Pelea, Dodonaea, Vaccinium, Geranium, etc attack living portions of trunks. Many of these kill plants, parts of plants, or stunt growth.

Predation and parasitism: Predation is probably mainly by rats, mongooses and birds. Parasitism is quite common. The braconid Doryctes palliatus has been reared from several of the larger species. The bethylid Scleroderma was reared from the new species from Sapindus in Kipuka Ki and from P. sugawai in Pittosporum on Kauai (see Davis report).

General abundance: As a rule, the adult cerambycids are rarely seen. Situations as described above for P. varians are very rarely encountered. However, with careful searching it is seen that many trees are affected by cerambycids and a great deal of boring is done by their larvae. In general, adults are short-lived, very active and elusive. Probably many of them rest on terminal branches, and are active in sunny weather but rarely seen in cloudy weather except when found in pupal cells. Larvae are more easily found than adults.

Host relationships: The plagithmysines (120 species) occur only in Hawaii and include all but 2 of the endemic species of Cerambycidae. Those 2 are large and bore in dead to rotten branches and logs on the ground, as a rule. The plagithmysines attack both living and recently dead portions of woody plants, as a rule still standing. They are remarkably host-specific. Since there is a general tendency towards woodiness in many groups of plants in Hawaii among genera which elsewhere are rarely or never woody, a number of groups of plants are attacked here that are not attacked outside Hawaii. About 53 families and 106 genera of native Hawaiian plants are woody or semi-woody. Of these, representatives of 27 families (52%), and 35 genera (33%) are known to be attacked by plagithmysines. However, unexpectedly, a number of the endemic genera of plants are not attacked. Of 22 genera of woody plants endemic to Hawaii, only 5 (22%) are attacked. There seems to be no direct correlation between the number of species in a genus of tree and the number of species of cerambycids attached to the host genus. Associations are mainly on the generic level (of trees) as far as can be certain at present.

There is some local speciation of cerambycids on the Big Island, within a genus of host plant, but this may be more from isolation of tree populations than from different species of a genus of host trees. On the level of the host tree species, however, nearly all the species attacked by the endemic cerambycids are endemic species of trees. Among the few exceptions are Nicotiana and Acacia decurrens.

There is a distinct relationship between host tree associations and the general abundance of the host trees. Many of the rare trees are not attacked. The only host genera now considered rare which are known to be attacked are Mezoneurum and Platydesma. As pointed out by Southwood (1960, 1961) there is a direct correlation between the abundance of a plant and the number of kinds of insects associated with it. The more common trees, which are native to the area concerned, and have been abundant over a long period of time, usually have greater numbers of associated insect species. This was verified for Hawaii by Southwood, and it holds true for the plagithmysines to a considerable degree. Although in general the Hawaiian cerambycids are highly host-specific and all are monoinsular endemics, the host associations are not evenly spread by host genera or species, but to a considerable extent relate to the abundance of hosts. On the other hand, a number of common plants do not yet have verified host records, or have only single isolated records, even though they have been searched. These are:

Boehmeria, Nototrichium, Pisonia, Broussaisia, Antidesma, Gossypium, Hibiscus, Viola, Cheirodendron, Reynoldsia, Tetraplasandra, Styphelia, Lysimachia, Myrsine, Labordia, Osmanthus, Alyxia, Phyllostegia, Nothocestrum, Solanum, Cyrtandra, Coprosma, Gardenia, Hedyotis, Psychotria, Clermontia, Cyanea, Scaevola, Artemisia, Lipochaeta and Tetramolopium.

Host associations are known for most of the plagithmysines, thanks to the efforts of Perkins, Swezey (1954), Davis and others. Recently, a number of new species have been found by searching in known hosts on islands where there were no records of cerambycids in those hosts. Thus, probably many new species will be added, and also additional hosts. Pittosporum, Ilex and Bidens were new hosts associated (all with new cerambycid species) in the past 3 years.

In the accompanying diagrams, host associations of plagithmysines are shown, together with an attempt to show phylogeny of the beetles. In making this study, the group has been reduced to a single genus, and several transfers of species are made between the subgenera (former genera). The former genus Neoclytarlus may consist of 3 different phyletic lines, originating from different ancestral Plagithmysus. What may be the most generalized species of the group are 2 from Hawaii. However, the most generalized member of the subgenus Plagithmysus may be nihoae, the westernmost, from Nihoa Island. There have been repeated transfers (founders) from one island to another within species-groups (oval outlines). Often the members of one species group are attached to one host tree or several related trees, but also often to unrelated common trees in the same environment. Dashed lines indicate subgroups. In contrast to the situation in the Drosophilidae, Kauai is relatively richer, and so is Hawaii. Also, the lobelioids and aralioids are not important hosts, as they are for drosophilids. Also, the plagithmysines clearly evolved from a single parent introduction.

Transect surveys: In addition to the trapping, below, searching of plants and cutting of wood was done at many points. The entire length of Transect 1 in the Kilauea For. Res. study area was searched more than once, with negative results. Trap log sections set out along this transect and along the logging road at right angles to it were also negative. The only positive results were in terminal branches of recently fallen koa trees near start of Transect 4 and beyond it (P. varians). In Myoporum outside fence short of study area, a number of larvae of P. perkinsi were found and are being reared. Davis reared a P. vitticollis from Rubus hawaiiensis from the same area. Searching along the Mauna Loa strip road, and particularly in Kipuka Ki and above the upper end of the road, was productive - 2 species in former and about 4 near latter.

Trapping results: (Cumulative)	Plagithmysus (P.) varians	P. (N.) claviger
Malaise trap, Kilauea For. Res. (Tr.1):	2	0
Malaise trap, Mauna Loa strip road:	56	60
W. Gagne: Pyrethrum knock-down, strip road:	4	15

Malaise trap, Honokowai, W. Maui (JLG 71-101....): 1 each of 2 n. spp. (trap set up 9 Oct. 1971)

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1961. The number of species of insects associated with various trees. J. Anim. Ecol. 30: 1-8.

Swezey, O.H. 1954. Forest entomology in Hawaii. An annotated check-list of the insect faunas of the various components of the Hawaiian forests. B. P. Bishop Museum Spec. Publ. 44: 1-266, ill.

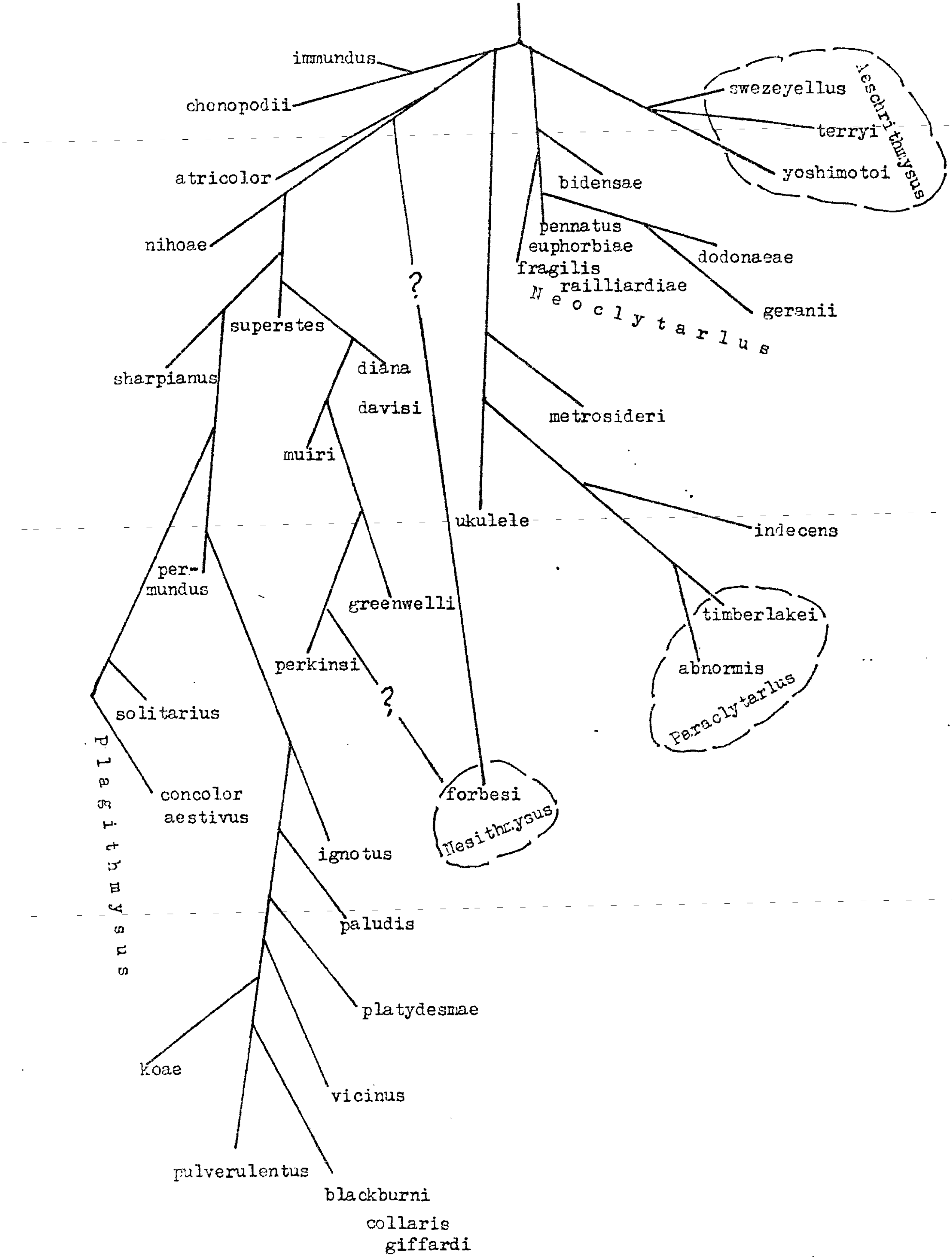
Publications resulting from project

Gressitt & Davis. 1971. New plagithmysines from Kauai, Molokai and Hawaii. Proc. Hawaiian Ent. Soc. 21 (1): in press.

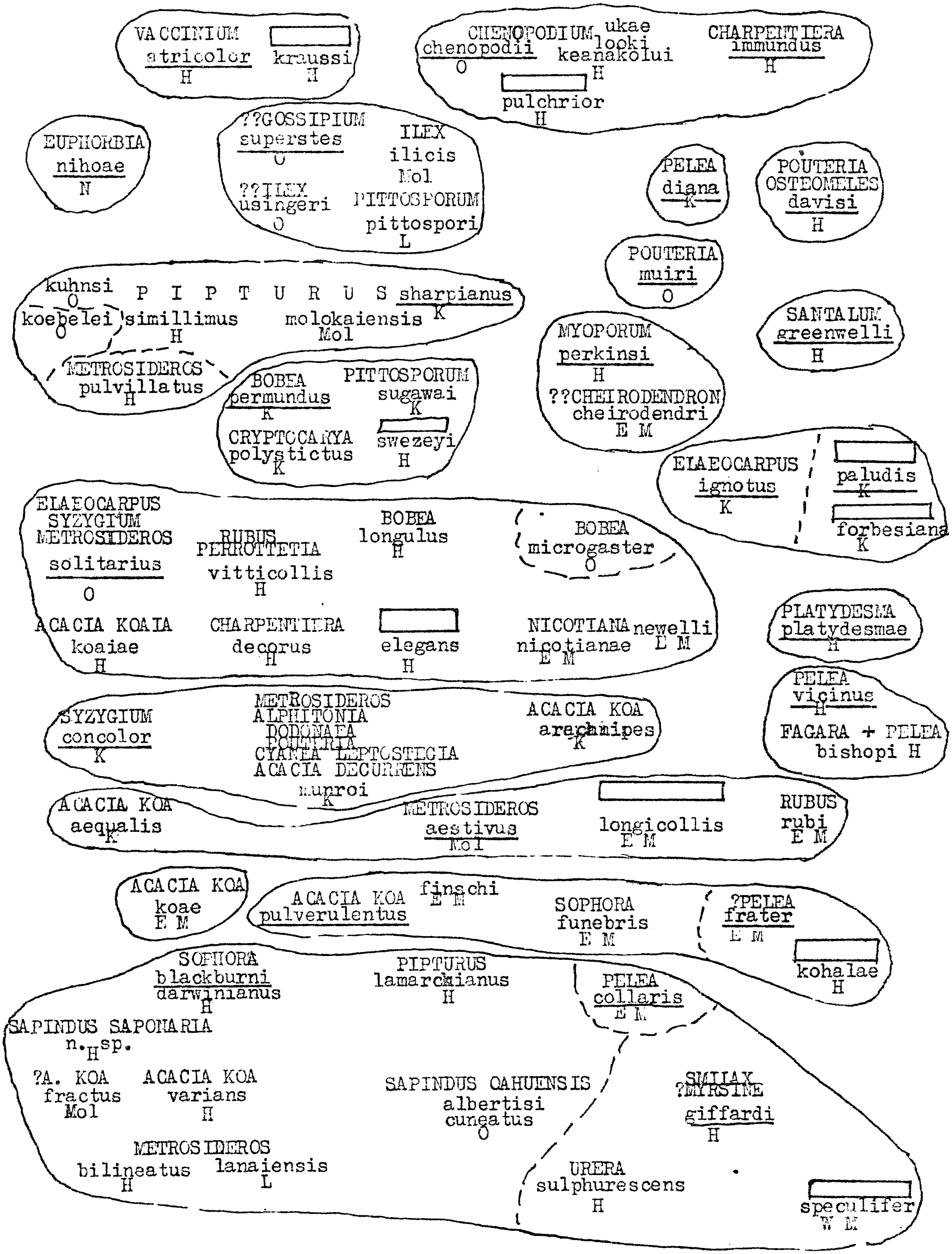
1972. Seasonal occurrence of the Hawaiian Cerambycidae (Col.). Proc. Hawaiian Ent. Soc. 21 (2): in press.

Gressitt. 1972. New plagithmysines from Molokai, Lanai and Maui. Pacific Insects 14 (1): in press.

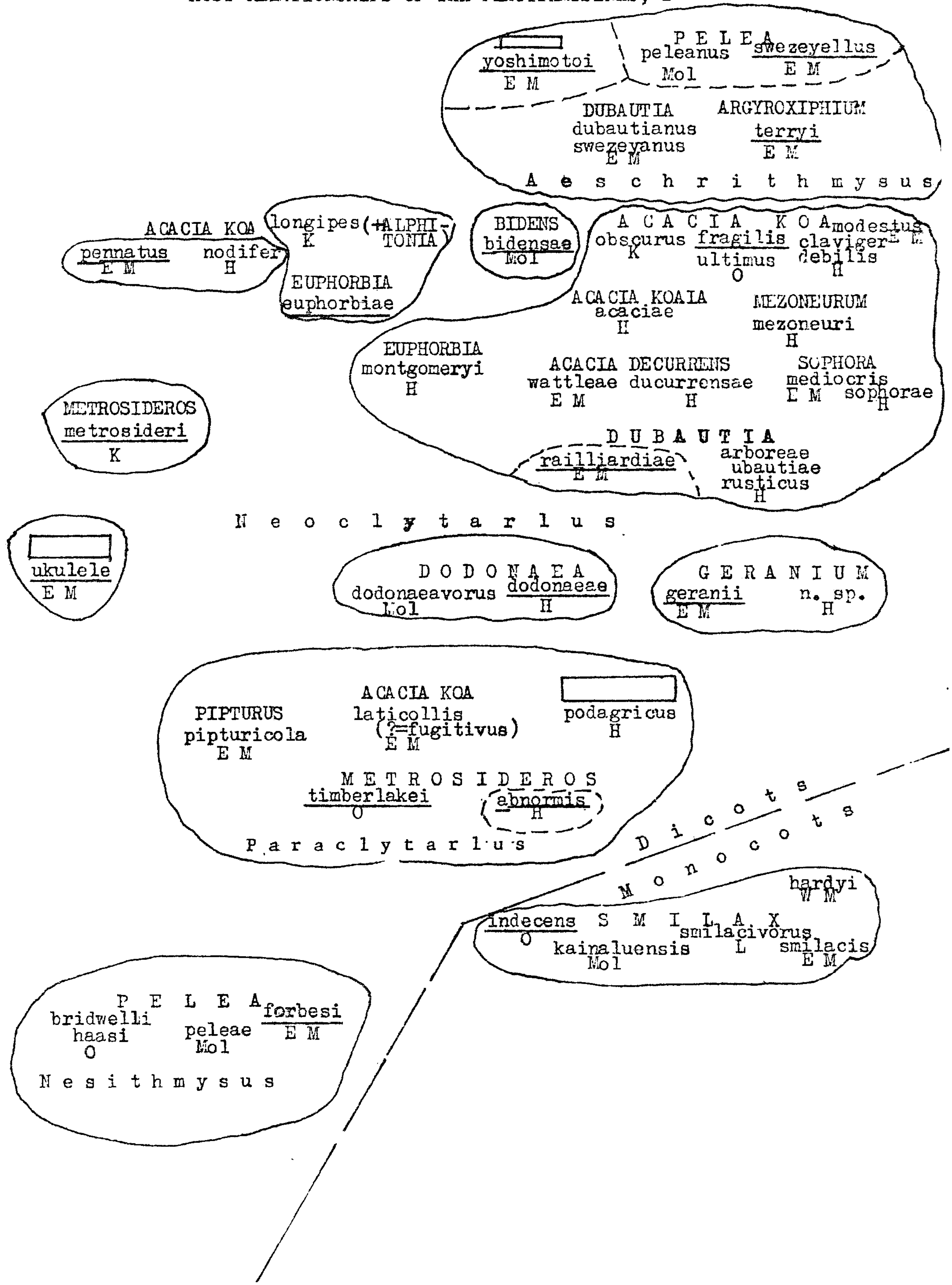
SUGGESTED PHYLOGENY OF PLAGITHMYSINI BY SPECIES-GROUPS



HOST RELATIONSHIPS OF THE PLAGITHMYSINES, 1



▭ - host unknown	K - Kauai	E M - E. Maui
- - - - subgroup	O - Oahu	W M - W. Maui
——— - species-group type -species	Mol - Molokai	H - Hawaii
	L - Lanai	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Aeschrithmysus
ACACIA KOA
pennatus
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nodifer
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longipes (+ALPHITONIA)
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euphorbiae
BIDENS
bidensae
Mol
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claviger
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ducurrensae
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mediocris
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sophorae
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METROSIDEROS
metrosideri
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DUBAUTIA
railliardiae
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arboreae
ubautiae
rusticus
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Neoclytarlus
ukulele
E M
DODONAEA
dodonaeavorus
Mol
dodonaeae
H
GERANIUM
geranii
E M
n. sp.
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PIPTURUS
pipturicola
E M
ACACIA KOA
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(?=fugitivus)
E M
podagricus
H
METROSIDEROS
timberlakei
O
abnormis
H
Paraclytarlus
Dicots
Monocots
hardyi
W M
indecens
O
SMILAX
smilacivorus
L
kainaluensis
Mol
smilacis
E M
PELEA
bridwelli
haasi
O
peleae
Mol
forbesi
E M
Nesithmysus

Progress report: Cerambycid studies on Sapindus saponaria (Sapindaceae) C.J. Davis

Manele, Sapindus saponaria is fairly common in Kipuka Ki, Mauna Loa Strip Road, Hawaii Volcanoes National Park. Swezey (1954) states that no native insects are attached to this tree and most of the few which occur on it are found on other trees as well. Plagithmysus darwinianus Sharp, an endemic Plagithmysine is one of the few native insects collected on Sapindus saponaria.

On August 5, 1971 a young Sapindus in the vicinity of the Hibiscadelphus plant community in Kipuka Ki had died fairly recently and the bark and wood disclosed numerous cerambycid larval galleries. Only a few exit holes were observed. The tree measured 15 centimeters at the base and was about 3,04 meters high.

Branch and trunk sections were cut and held in three rearing boxes under Insectary conditions in Honolulu. The mean maximum temperature was 26.7 C. Emergence results are shown on Table 1.

It will be noted that an endemic cerambycid, Plagithmysus sp. emerged from this material. Species identification is pending. This is the first record of an endemic plagithymysine being reared from this tree species on Hawaii.

For Lot 1, Plagithmysus stopped emerging on September 27, for Lot 2, October 4, and Lot 3, September 21. A total of 44 beetles emerged for the three lots. A total of 149 bethlylids, Sclerodermus perkins Ashmead emerged, but the relationship between Plagithymysus and Sclerodermus was not definitely established. Bridwell (1920) established a parasitic relationship for some native and exotic species of cerambycids and other insects for bethlylids and very likely the same is true for Plagithmysus sp. ex Sapindus.

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Emergences from branches and trunk of <u>Sapindus saponaria</u> "Menele" collected at Kipuka Ki, Mauna Loa Strip, Hawaii Volcanoes National Park, 1295 meters collected on August 5, 1971.

	Lot #1	Lot #2	Lot #3		Total
A --- 15 x 35 CM		A --- 8 x 32 CM	A --- 5 x 30 CM	F --- 7 x 12 CM	
B --- 15 x 35 CM		B --- 6 x 27 CM	B --- 4 x 20 CM	G --- 3 x 26 CM	
C --- 15 x 35 CM		C --- 4 x 33 CM	C --- 3 x 28 CM	H --- 2.05 x 24 CM	
D --- 15 x 35 CM		D --- 8 x 33 CM	D --- 3 x 23 CM	I --- 4 x 23 CM	
		E --- 8 x 30 CM	E --- 2 x 28 CM	J --- 7 x 12 CM	
<u>Plagithmysus</u> sp.	20	19	5		44
<u>Sclerodermus perkins</u> Ashmead	15	115	19		149
Ichneumonid <u>Pristomerus</u> sp.			1		1
Micro leps	15	2	2		19
Psocids		10			10
Total ---	50	146	27		223

Phytophagous insects - sap & seed feeders (Heteroptera)

Objective 1. FACTORS AFFECTING SPECIATION

The speciating group that I have chosen is the genus Nesiomiris Kirkaldy (Miridae) which comprises ca. 55 spp. which are host specific to endemic trees in the Araliaceae and the Aquifoliaceae. The non-speciating group that I have chosen is the genus Koanoa Kirkaldy (Miridae), which contains 2 species of generalist predators. (See original program proposal for statement of following hypotheses).

Hypothesis 1 (a). Most of the species of Nesiomiris are various shades of green which generally match their leaf habitat substrate. However, several host species of Tetraplasandra (Araliacae) have white or mottled white leaf undersides. Four of 5 Nesiomiris species specific to these hosts are white or mottled. It is postulated that this is the result of selection pressure by birds for a phenotype which most closely matches that of the substrate. These bugs are also behaviorly modified in that they remain stationary on the substrate when the habitat is disturbed rather than scurrying frenetically about as do the green species. These findings correlate with similar hypothesis to explain the unusual behavior of the endemic picture-wing Drosophilidae (Diptera).

Hypothesis 1 (b). The Nesiomiris would appear to have more potential of developing isolating mechanisms because of their tendency to host specificity, the development of a number of specific host plants, the potential then for co-evolution with the host and their larger body size which would lessen the chances of interisland dispersal. One species complex shows a tendency to flightlessness.

Hypothesis 1 (c). All but 4 species of Nesiomiris are monoinsular endemics, the remainder become progressively range-restricted, the older the island. This couples with host isolation. This contrasts with Koanoa which appears to be neither host specific nor habitat specific. It also feeds at a higher trophic level and is smaller bodied and not monoinsular endemic.

The Founder Principle would help to explain the monophyletic, monoinsular species assemblages in the genus Nesiomiris.

Objective 2. STABILITY & FRAGILITY OF HAWAIIAN ECOSYSTEMS

The emphasis here is on the foliar arthropods of Acacia koa and Metrosideros collina ssp. polymorpha var. incana with particular reference to the heteropterous sap and seed feeders.

SAMPLING MODIFICATIONS SINCE TECHNICAL REPORT #1

1) Plan

Some additional sampling sites have been necessitated. These sites have been selected to conform more closely with phenological study sites of Project B-3. The 9 sites were at sea level, 2500', 3900' (2 sites), 4000', 5400' (2 sites), 6600' and 7000'. From 4000'-6600' koa was also sampled. Logistics and the need for sample uniformity has dictated that the sampling be restricted to mature host specimens at each site, rather than an arbitrary selection of age classes. At each site the sample was replicated once for each host. Thus a total of 9 times 2 (Metrosideros) plus 4 times 2 (Acacia) or 26 samples for each sample run were taken once every two months. This run usually required two weeks since several days were usually lost to inclement weather and moving sampling gear. Individual Metrosideros trees were sampled at sea level and at 5400' along the Mauna Loa Strip Road because the trees are so scattered at these sites.

2) Equipment

A Dyna-Fog '70' insecticide fogger for pyrethrum application, manufactured by Curtis Dyna Products, was found to be the easiest applicator to handle in the often rough terrain of the Mauna Loa Transect. This self-contained machine (with but one moving part) and filled weight of 27 lbs was easily hand carried to the sample site (sometimes considerably removed from a road) and roped up to a suitable level to fog the sample.

For the scattered Metrosideros populations at sea level and at 5400' the technique was modified to single tree sampling. A zipper was installed in a sample canvas funnel such that it could be installed about the trunk of the tree to be sampled. The fallen sample was aspirated off the sample sheet. In the Kilauea Forest koas were also so scattered that it necessitated proping the $6m^2$ sampling funnel beneath a crown rather than typing each of the 4 corners to a tree.

3) Timing

Samples were taken at various times during the day and evening to test for activity patterns in the foliar community. It is anticipated that each sample site will be resampled the following year on or near the same date for yearly comparisons. Total recovery of the arthropod community after the stress of fogging is probably well within this period (see Bulan & Barrett, 1971).

4) Justification

The method was chosen because of its ease of sampling the whole foliar crown with a minimum of disturbance, the minimization of debris in the resulting sample with a consequent minimum of sample loss. It has the potential of comparison with a similar sampling of 5 years duration in pine plantations in Central Ontario (Martin, 1966; Gagné & Martin, 1968) and that of Yamashita (1970a, b) for the Japan IBP/CT-S.

It is recognized that no single technique is truly unbiased for any single method of extraction for no group is very uniform in controlability. Despite these drawbacks, no feasible alternative method for whole foliar crown sampling seems available.

SAMPLING RESULTS

1) Changes in abundance

The relative density of the arthropod community decreased with altitude on both hosts. Populations were generally higher on Acacia than on Metrosideros, however, the exotic acacia psyllid (Psylla uncatoides) skewed that foliar community upwards.

2) Changes in number of species in each biota group

When assigned by ecological niche (Figure 1) the phytophagous component decreased with altitude gain while the saprophagous and epiphytic associates increased (Figure 2). Hemiptera comprised the bulk of the phytophagous group while Psocoptera constituted most of the latter group.

3) Changes in adaptation

Fifteen orders of arthropods were present on each host. Ants, roaches, endemic arboreal crickets, exotic isopods, and amphipods generally "dropped out" of the foliar community between 4000'-5000'. Although a complete identification of all taxa is still underway, it is evident that the richest communities are contained in the 3900-5000' range on Metrosideros and at the lowest elevations of Acacia (ca. 4000') (Figure 3). Coleoptera appear to be the richest in terms of taxa although this might change when the spiders are more completely identified.

4) Changes in composition of native and exotic organisms

Indications are that the fauna in the Kilauea Forest is the most "pristine" in that this site contained the lowest percentage of identifiably exotic taxa. On Acacia, P. uncatoides comprised the bulk of this component. On Metrosideros, ants were the major exotic group and they became increasingly prevalent towards sea level. Exotic taxa decreased ascending the transect. (Figure 4).

5) Exotic penetration and climatic factors

Social species (ants) and polyphagous species (e.g. the flatid bug, Siphanta acuta and the roaches) had the highest "penetrance" of native communities. S. acuta was present at all elevations on Metrosideros.

Most exotics on Metrosideros were present below 4000'. A comparison with the relatively wet site at 5400' in the Kilauea Forest with a drier site at the same elevation on the Mauna Loa Transect revealed that the exotics were more prevalent in the drier site.

BIOMATHEMATICAL RELATIONSHIPS

Mathematical and statistical refinements of species diversity measures and its correlation with other variables is a rapidly developing research area. It is now difficult to select an analytic method because of the changing nature of biostatistical analyses and its conceptual framework and lack of consensus on methods most appropriate to analyse a particular problem.

There have been several recent critical analyses of stability and diversity measures. The Probability of Interspecific Encounter is argued as an effective parameter by Hurlbert, 1971. For samples containing many species such as mine do, Bullock (1971a) demonstrated that the log-series and the index of diversity are good measures for sample description. For sample comparison he (1971b) showed that Kendall's rank correlation coefficient is also effective. Deevey (1969) claimed that "species composition parameters will have clearest significance when calculated on a "taxocene" (a taxonomic segment of a community or association) (see Fig. 3). These methods will be programmed for computer analysis.

COOPERATION WITH OTHER INVESTIGATORS

I am identifying the Hemiptera from pitfall traps and lava tubes (Project C-9). My data will be compared with that derived from a different method of sampling Metrosideros arthropods (Project C-5) and material I have obtained of the acacia psyllid and Metrosideros psyllids is being supplied to the respective projects (Project C-5 and C-6). A number of collaborators are identifying the arthropods derived from my samples, e.g. Gressitt - cerambycid beetles (Project C-3) and Steffan - sciarid flies (Project C-2).

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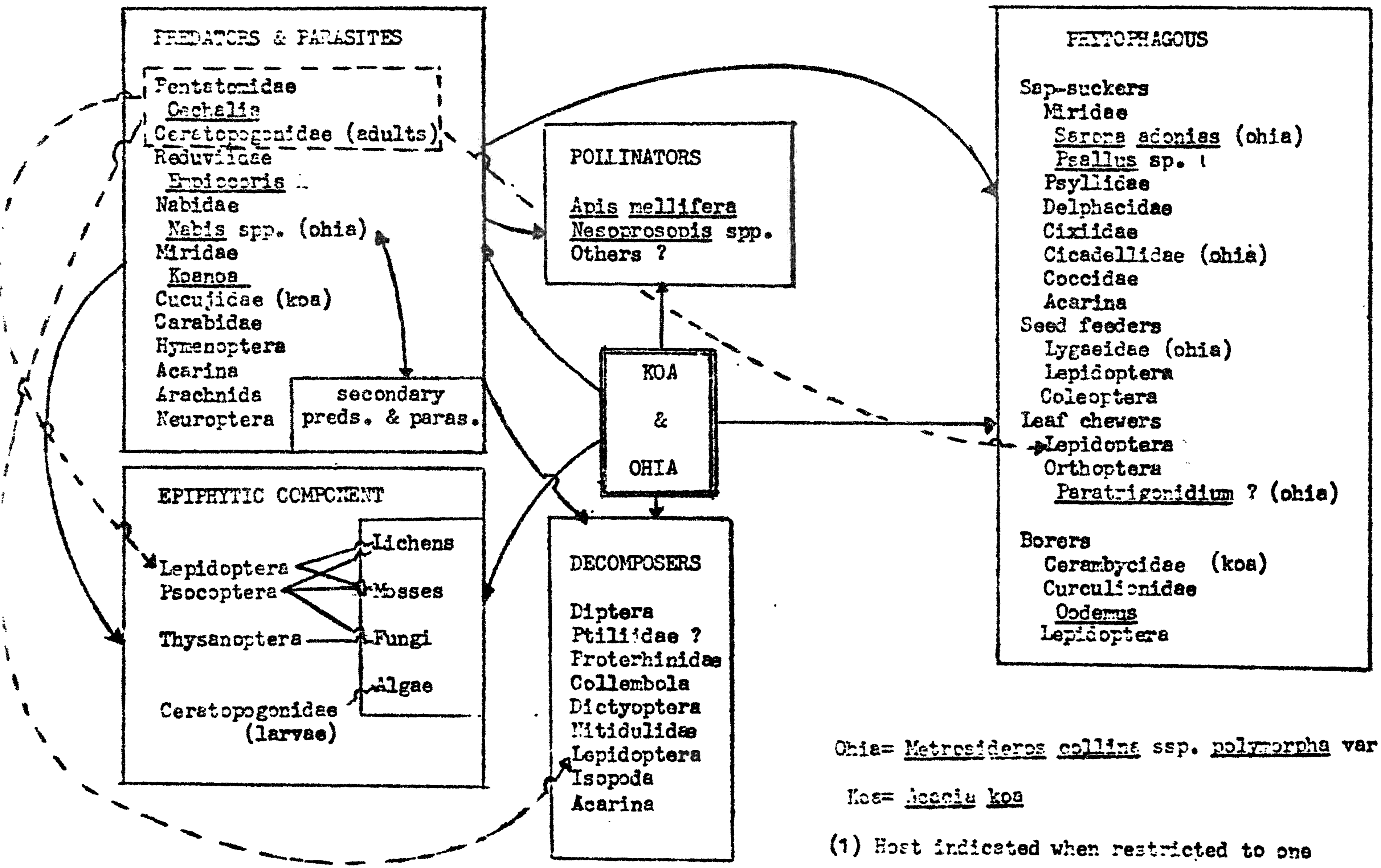
FIGURE 1. ECOSYSTEM MODEL FOR ENTOMOLOGICAL COMMUNITY ON LEAVES & TWIGS OF KOA & OHIA [1,2]

IDEALIZED INTERACTION MODEL



Ohia= *Metrosideros collina* ssp. *polymorpha* var. *incana*

Koa= *Acacia koa*

(1) Host indicated when restricted to one

(2) ? indicates community position uncertain

FIGURE 2. FOLIAR ARTHROPOD COMMUNITY STRUCTURE ON MAUNA LOA TRANSECT

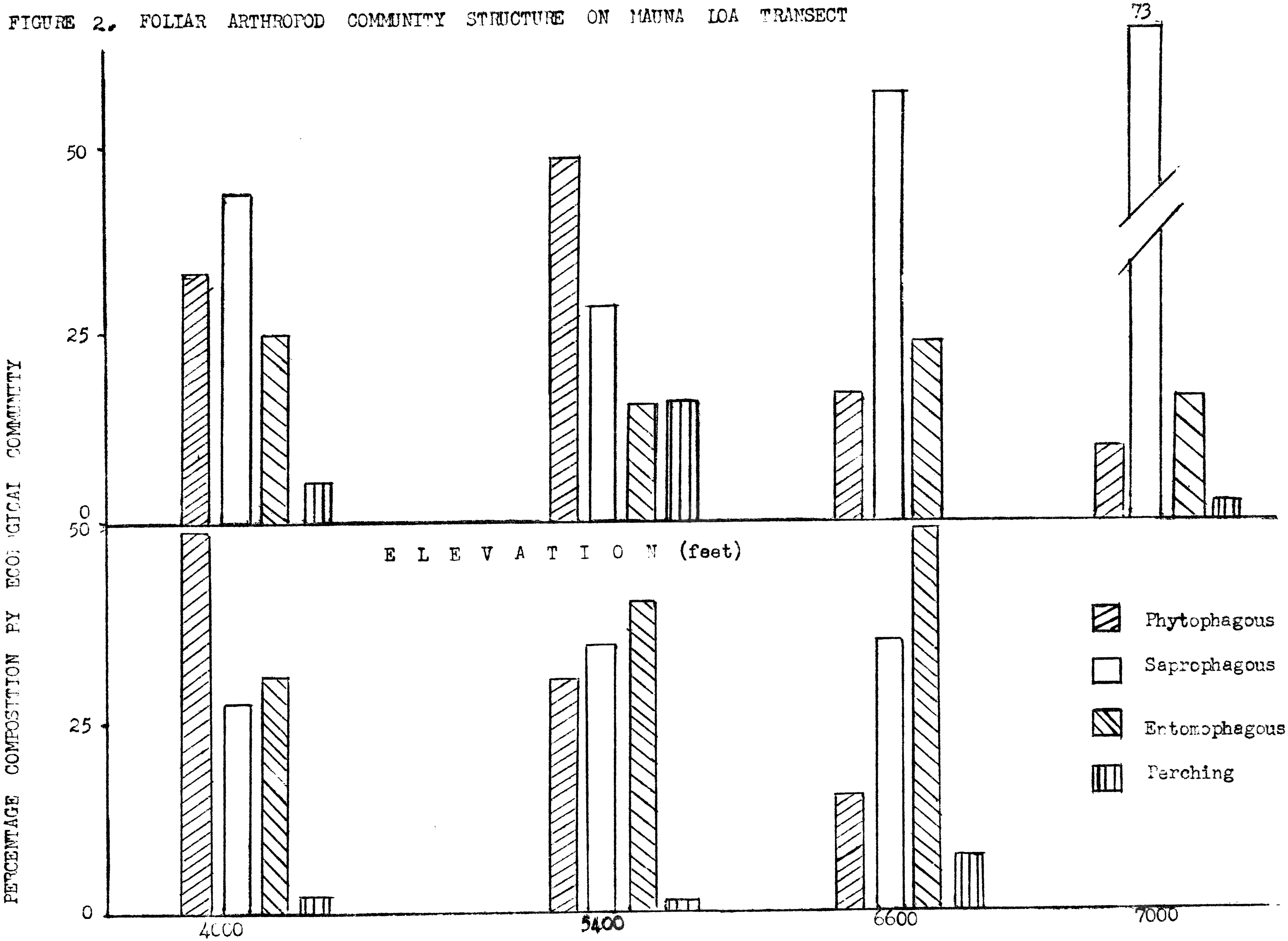


FIGURE 3. RELATIVE NUMBER OF INSECT TAXA, ARRANGED IN TAXOCENES, ON MAUNA LOA TRANSECT

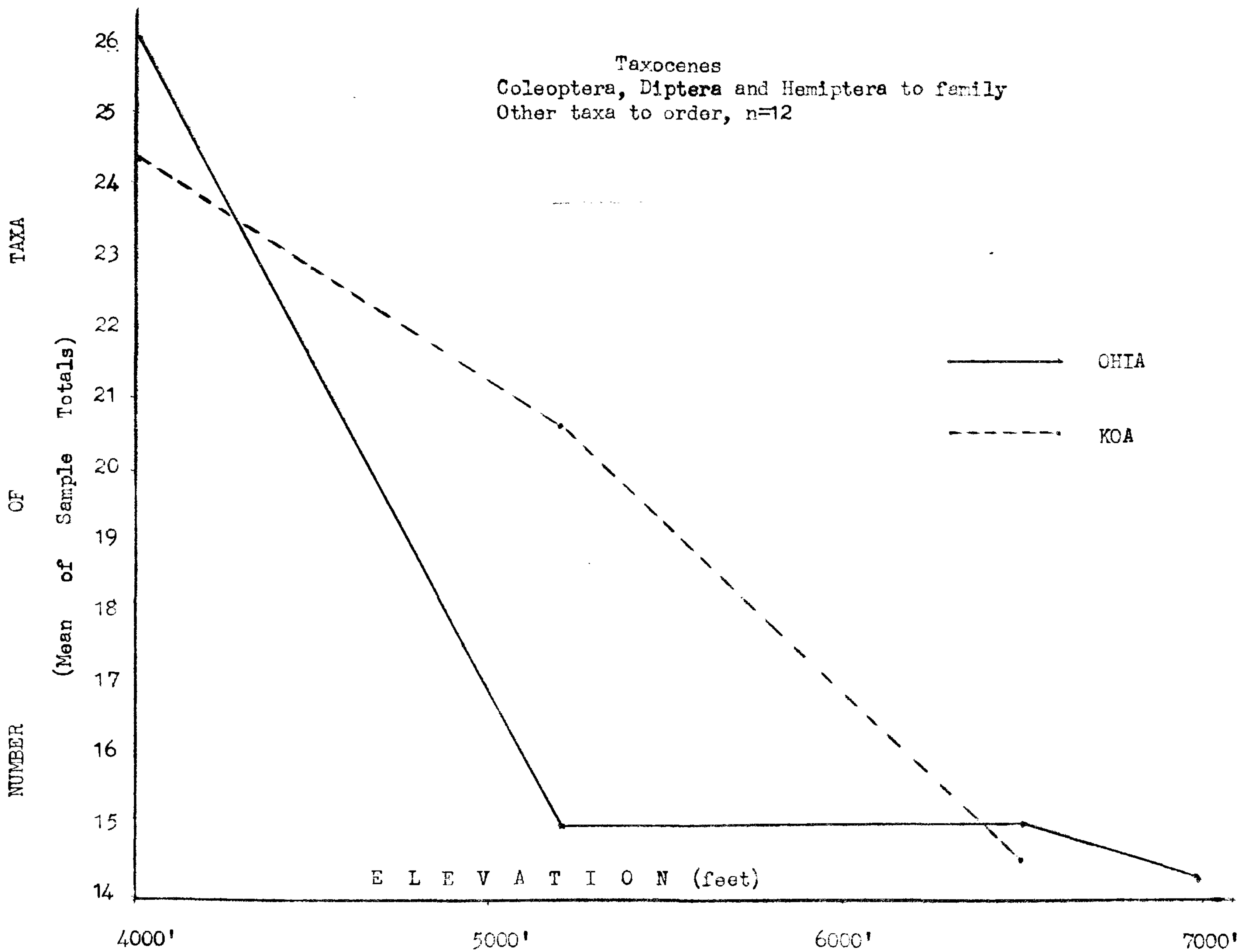


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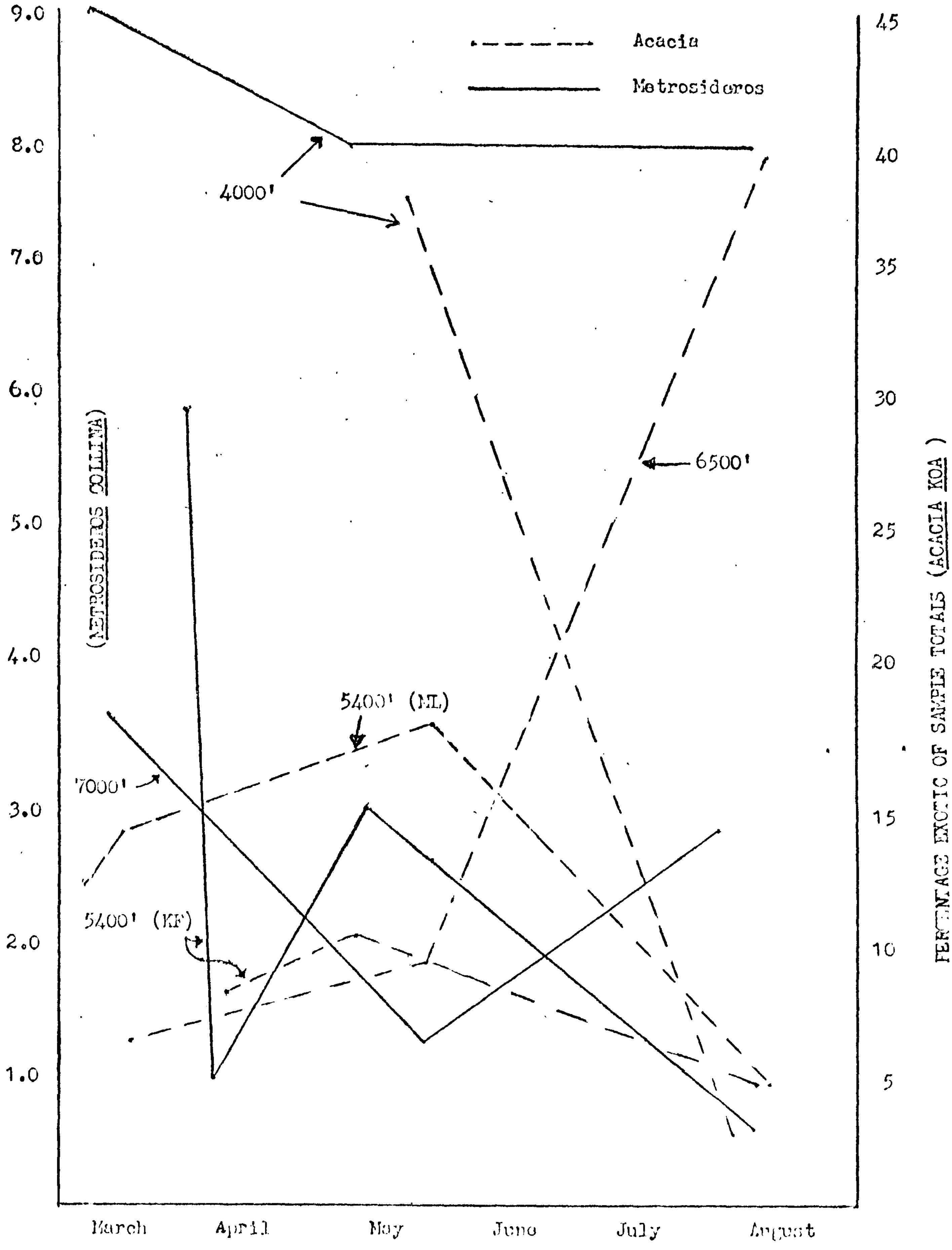
FIGURE 4. COMPOSITION OF EXOTIC COMPONENT IN FOLIAR ARTHROPOD COMMUNITIES



Progress report on effects of sap-sucking Homoptera on Hawaiian ecosystems.

J.W. Beardsley
John R. Leeper

Research on the koa psyllid, Psylla uncatoides (Ferris and Klyver), was begun in May 1971. The principle study sites were located along the Mauna Loa transect (4300, 5300, and 6600 ft.). A study site was also established at the Koaia Reserve in the Kohala Mts. (3000 ft.) for comparative purposes. Sampling techniques have been worked out and have, for the most part, been found satisfactory. Emphasis has been placed on following the population fluctuations of the psyllid and the relationship between the psyllid and its host plant, Acacia koa.

The psyllid favors to lay its eggs and the nymphs favor development on new terminal growth. The psyllid infestations on new growth can reach a point where terminal die-back on the plant will occur. Table 1 shows the averages of the percent new growth at each site for each field trip. The averages are based on 3-100 counts of terminals. By taking these readings we can roughly project what the psyllid population is likely to be (either high or low) in the near future, or what it has been in the past. A numerical projection of probable psyllid population size can not be given as yet, since other factors influential in determining the psyllid population must be taken into account and have yet to be studied. It should be noted that the absence of new growth at 6600 ft. along the Mauna Loa transect was not due to die-back associated with a psyllid infestation but appeared to be associated with the natural phenology of the trees at that elevation. A second flushing of new growth is beginning along the Mauna Loa transect. Above and below the 4300 ft. site the percent new growth is significant but at that site there is only a negligible percentage. When flushing does occur, it is on the terminals that do not have heavy budding. Therefore the recent percentages do not include those terminals. It is not yet known whether this is the start of next season's flush or whether it is only a winter flush of new growth. Whatever the situation, it will be interesting to see what effect this flushing will have on stimulating the psyllid populations to increase in the following winter months. The psyllids are not attracted to the buds to lay their eggs or to feed on. Therefore, budding is being observed but not followed closely.

Table 2 shows the adult psyllid population estimates. The figures represent the number of psyllid adults collected in a 3 minute D-vac sample. The numbers were arrived at by an actual count for the lower sized figures and the larger sized figures represent a volumetric estimation. A comparison of this data with the percent new growth data shows that a drop in the adult population follows the loss of new growth. The nymphal populations (Table 3) also decrease after loss of new growth. The decreases in the nymphal populations more closely follows the decrease in new terminal growth than does the decrease in the adult populations. This is an indication that the adult stage is the longer lived stage. Koehler et al. (1966) substantiated this in their study of the life history of P. uncatoides.

The adult psyllid populations can easily be sampled with the D-vac since a disturbed adult will jump and can then easily be sucked into the machine. The nymphs do not jump when disturbed but cling to the plant. Therefore, another method had to be devised to obtain sample estimates of the nymphal

Table 1. Percent New Terminal Growth (Average of 3-100 Counts).

Date*	Mauna Loa Strip			Koaia Reserve
	6600	5300	4300	3000
5/15/71	73.0	73.0	59.8	20.0
6/14/71	67.6	0.0	0.0	81.3
7/19/71	70.6	0.0	0.0	88.0
8/2/71	69.3	0.0	0.0	96.0
9/1/71	66.3	0.0	0.0	95.0
10/3/71	0.0	0.0	0.0	81.0
10/31/71	0.0	0.0	0.0	61.6
11/5/71	45.3	63.3	<15.0	66.6

Table 2. Adult Psyllid Population Estimate (3 Min. D-vac Sample of Branch Terminals).

Date*	Mauna Loa Strip			Koaia Reserve
	6600	5300	4300	3000
6/14/71	101	3000	5500	--
7/19/71	657	1000	750	214
8/2/71	576	840	453	775
9/1/71	464	312	195	1800
10/3/71	224	243	28	4800
10/31/71	79	193	14	1800

Table 3. Nymphal Population Estimate (Total of 10-4 in. Terminal Samples).

Date*	Mauna Loa Strip			Koaia Reserve
	6600	5300	4300	3000
5/15/71	158	1,903	20,392	99
6/14/71	23	10	1,072	46
7/19/71	403	0	1	20
8/2/71	404	12	1	23
9/1/71	311	12	3	283
10/3/71	10	12	1	53
10/31/71	3	6	0	12

* The Koaia data was collected ±3 days from dates listed.

populations. The nymphal population estimates for each site were obtained by counting the nymphs on 10-4 inch terminal samples. This method is rather laborious and time consuming. Harris (1971) has described a method by which he separated the pear psyllid, Psylla pyricola, from pear foliage using a berlese funnel. This method facilitated his counting the nymphs. Harris's method is being used to count the nymphs on A. koa terminals collected on the last field trip to determine its feasibility in separating P. uncatoides nymphs from the terminals.

No parasites of P. uncatoides have been found in Hawaii. Predators are present but none of them appear able to control the psyllid populations. The principle predators at the Koaia Reserve site are coccinellids while there does not appear to be any one principle predator along the Mauna Loa transect. Dr. Beardsley has found P. uncatoides in Australia and has also found a parasite of its nymphal stage. He is working with Mr. Davis of the State Department of Agriculture to introduce the parasite to Hawaii.

Looking ahead, we plan on following the above trends more closely by increasing the frequency of sampling at the present sites as well as at additional sites at 4000, 4800, 6000 ft. along the Mauna Loa transect and in the Kilauea Forest. We are particularly interested in the effects of climate on the psyllid populations and will be placing more emphasis on that relationship. Mr. Davis has expressed an interest in whether the psyllid can mechanically transmit the koa rust, Uromyas koae. We will also start researching on that possibility.

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Progress report on faunal research on
Metrosideros

T. Nishida
F. H. Haramoto
L. Nakahara

Branchlet, bark, and duff samples from Metrosideros collina polymorpha var. incana were collected on a bimonthly schedule since November, 1970 from plots established along a transect on Mauna Loa at elevations of 500, 3400, 3500, 3800, 4000, and 7000 feet. More recently, October 1971, similar samples were begun to be taken from two more plots established along the same transect at elevations of 5500 and 8000 feet. Some of these plots are being used by botanists (Parter and Lamoureux) and other entomologists with the objective of integrating or complementing our findings. Data obtained from these samples and from D-Vac samples show that the arthropod communities associated with this plant are very rich and complex (Fig. 1). To date some 150 different species of arthropods have been recovered from these plots and identified to various taxonomic categories. Identification of most of them to specific level was not possible because they appear to be new species. Also, since the biologies of most of them are still unknown, their role and niche in the Metrosideros ecosystem remain uncertain. Tentative groupings of them according to their feeding habits are presented in Tables 1, 2, and 3.

Greatest diversity in the arthropod communites of Metrosideros was evident in the plots at 3500 and 4000 feet and fewer arthropods occurred in the plots further down or up the transect from these elevations. For example, in the duff samples collected in April 1971, there were 27 species with 2632 individuals at 3800, 21 species with 322 individuals at 7000, and 27 species with 463 individuals at 500 feet. In each plot, arthropods were most numerous at the ground level and fewest at the foliage level. On the same sampling date mentioned earlier, 27 species with 2632 individuals were recovered from the duff sample, 22 species with 797 individuals from the bark sample, and 14 species with 653 individuals from the branchlet sample at 3800 feet. Although mites outnumbered the other arthropods in most of the samples, only 2 out of the 79 different species of mites were primary consumers of Metrosideros (Table 1). Insects were the predominant phytophagous arthropods of Metrosideros and these were recovered primarily from the foliage level. Exotic species of arthropods were numerous in the plot at 500 feet but decreased in number with increase in elevation.

Besides identifying and enumerating all of the arthropods associated with Metrosideros, more detail studies were conducted on psyllids because they appear to have a greater influence on Metrosideros than any of the other phytophagous arthropods. Results obtained thus far show that there are four species of psyllids intimately associated with this plant on Mauna Loa. These are: Trioza n. sp. 1 (previously regarded as T. ohiacola) forming flat galls on the leaves, Trioza n. sp. 2 forming cone galls on the leaves, stems and flower buds, Trioza hawaiiensis forming stem galls, and Kuwayama minuta forming pit galls on the upper surface of leaves. The first species was widely distribted from 500 to 7000 feet while the others were more restricted in their distribution (Table 4). Also, in a given plot these psyllids were not randomly distributed but showed some preference to certain trees. Because of this habit, certain trees; especially those infested by T. hawaiiensis, were badly deformed and stunted. Preliminary studies on the biology of Trioza n. sp. 1

were also conducted. The fifth instar nymphs of this species emerged from the galls through the lower surface of the leaves and molted into adults within an hour. After mating, the females deposited their heavily sclerotized black eggs in the vicinity of expanding leaf buds. The eggs hatched within a month and the first instar nymphs crawled onto and fed on the undersurface of the flushing leaves. A flat gall formed around each of the nymphs, and the nymphs spent their remaining stadia of one to three months within the galls.

Such factors as seasonal variations, predators, parasites, and phenology of Metrosideros undoubtedly have significant effect on the psyllids as well as the other arthropods. Elucidation as to how these factors interact with each other will shed some light on the evolution and speciation of arthropods on Metrosideros in Hawaii. To accomplish this, we fully appreciate the fact that an integrated effort by both botanists and other entomologists are needed.

FIGURE 1. INTERACTION MODEL OF THE METROSIDEROS ECOSYSTEM
Arthropod community

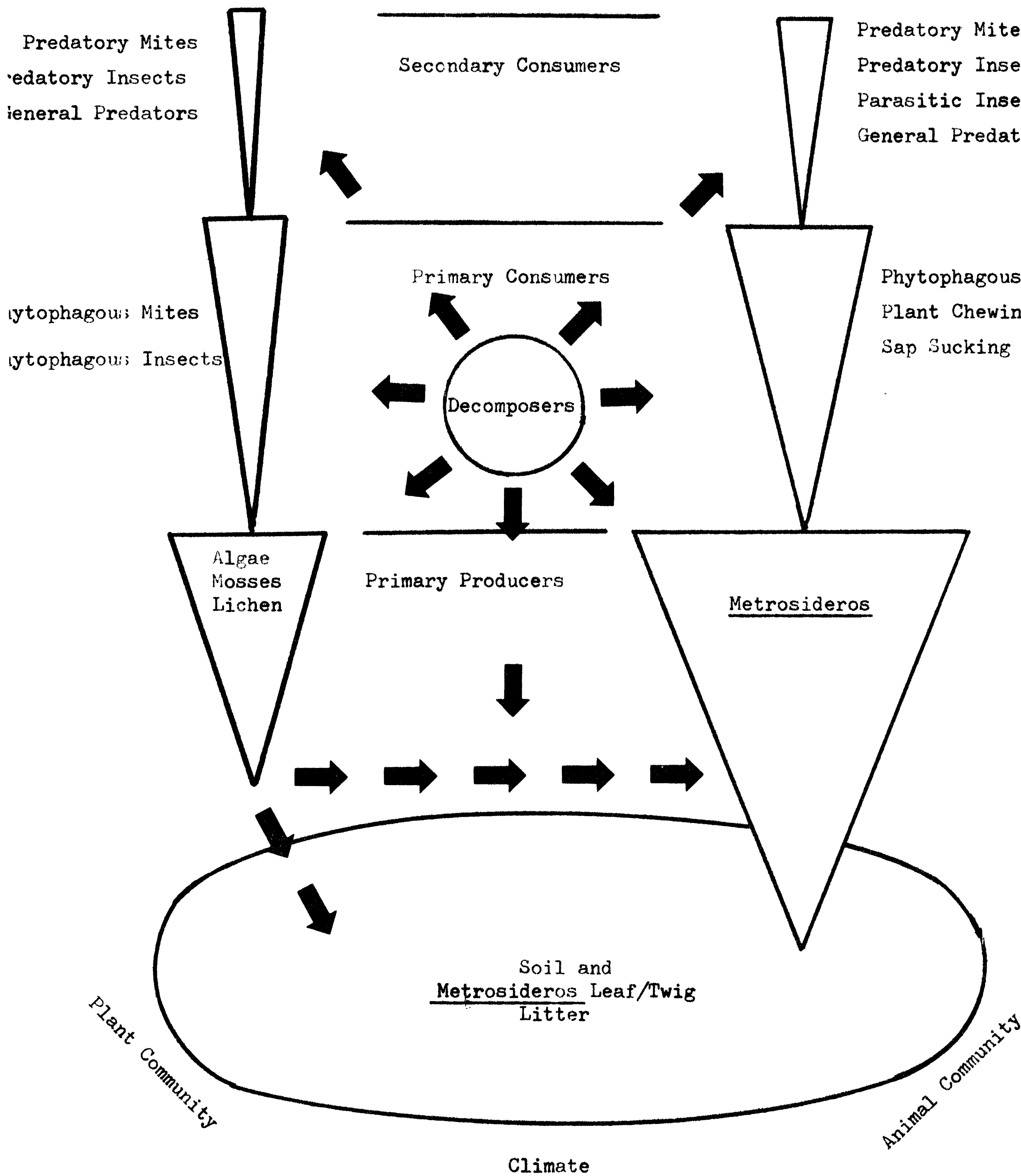


Table 1. Phytophagous arthropods found in association with Metrosideros from November 1970 to November 1971.

Arachnida	Locality*	No. Species	Insecta *et al.*	Locality*	No. Species
PROSTIGMATA			THYSANOPTERA		
Eriophyidae	L	1	Phlaeothripidae	L	1
Tarsonemidae	L	1	ORTHOPTERA		
			Gryllidae	L	1
			HOMOPTERA		
			Coccidae	L	2
			Delphacidae	L	1
			Diaspididae	L	1
			Flatidae	L	1
			Pseudococcidae	B L	2
			Psyllidae	L	4
			HEMIPTERA		
			Lygaeidae	L	1
			Miridae	L	1
			Plataspidae	L	1
			COLEOPTERA		
			Proterhinidae	B	1
			Scarabaeidae	L	1
			LEPIDOPTERA		
			Carposinidae	L	1
			HYMENOPTERA		
			Colletidae	L	1
TOTAL		2			20

* D= duff sample
B= bark sample
L= branchlet sample

Table 2. Saprophagous, mycetophagous, etc. arthropods found associated with Metrosideros, November 1970 to November 1971..

Arachnida	Locality*	No. Species	Insecta *et al.*	Locality*	No. Species
MESOSTIGMATA			ISOPODA		
Uropodidae	D	1	Sowbugs	D B	1
ASTIGMATA			DIPLOPODA		
Acaridae	D B	1	Millipedes	D B	1
Anoetidae	B	1	COLLEMBOLA		
Czenspinskiidae	L	1	Achorutidae	D B	2
CRYPTOSTIGMATA			Entomobryidae	D L	2
Achipteriidae	D B L	1	Isotomidae	B	1
Astegistidae	B	1	Onychiuridae	D	1
Brachychthoniidae	D B	1	Sminthuridae	D B	2
Carabodidae	D B	1	CORRODENTIA		
Ceratozetidae	B	1	Elipsocidae	D B L	1
Ctenacaridae	D	1	Liposcelidae	D B L	1
Cymbaeremaeidae	B L	1	Psocidae	D B L	1
Eniochthoniidae	D	1	THYSANURA		
Epilohmanniidae	D	1	Lepismatidae	D B	1
Eremaeidae	D	1	COLEOPTERA		
Euphthiracaridae	D B	2	Ciidae	B	1
Galumnidae	D B	2			
Haplochthoniidae	D	1			
Haplozetidae	D	1			
Hypochthoniidae	D	2			
Liodidae	D B	1			
Malaconothridae	D B	1			
Microzetidae	D	1			
Mycobatidae	B	1			
Nanhermanniidae	D B	1			
Nothridae	D B	2			
Oppiidae	D B L	3			
Oribatulidae	D B L	3			
Perlohmanniidae	B	1			
Phthiracaridae	D B	2			
Sphaerochthoniidae	D	1			
Tegoribatidae	D	1			
Trhypochthoniidae	B L	1			
TOTAL		41			15

*D= duff sample, B= bark sample, L= branchlet sample.

Table 3. Entomophagous arthropods found on <u>Metrosideros</u>, November 1970 to November 1971.

Arachnida	Locality*			No. Species	Insecta *et al.*	Locality*			No. Species
PROSTIGMATA					DERMAPTERA				
Anystidae		B	L	1	Earwigs	D	B		1
Bdellidae	D	B	L	1	THYSANOPTERA				
Cryptognathidae	D			1	Thripidae	D	B	L	1
Cunaxidae	D		L	1	NEUROPTERA				
Erythaeidae			L	1	Chrysopidae			L	1
Eupodidae	D			1	Hemerobiidae			L	1
Nanorchestidae	D			2	HEMIPTERA				
Pachygnathidae	D	B		1	Nabidae			L	1
Penthalodidae	D			1	COLEOPTERA				
Pseudocheylidae			L	1	Coccinellidae		B	L	6
Raphignathidae		B		1	Staphylinidae	D			1
Rhagidiidae	D			1	HYMENOPTERA				
Scutacaridae		B		1	Agriotypidae			L	1
Stigmaeidae			L	3	Braconidae			L	2
Tydeidae		B		1	Encyrtidae			L	4
MESOSTIGMATA					Eulophidae			L	2
Ameroseiidae			L	1	Eupelmidae			L	1
Ascidae	D	B	L	2	Evaniidae			L	1
Cheyletidae	D	B	L	3	Formicidae		B	L	1
Ologamasidae		B		1	Ichneumonidae			L	3
Parasitidae	D	B		1	Mymaridae			L	1
Parholaspidae	D	B		2	Platygasteridae		B		1
Phytoseiidae	D	B	L	5	Pteromalidae			L	1
Podocinidae	D			1	Scelionidae			L	1
Rhodacaridae		B		1	Vespidae			L	1
Veigaiaidae	D			1					
ARANEIDA									
Argiopidae			L	1					
Salticidae			L	1					
Theridiidae			L	1					
PSEUDOSCORPIONIDA									
Pseudoscorpions	D	B		1					
TOTAL				40					32

* D= duff sample, B= bark sample, L= branchlet sample

Table 4. Species of Psyllids and Their Galling Incidence on Metrosideros.

Elevation (feet)	Galling Index*				
	Trioza n. sp. 1	Trioza n. sp. 2	Trioza hawaiiensis	Kuwayama minuta	Total**
500	1.8	0.2	0.0	0.0	2.0
3500	2.2	2.4	0.1	1.0	5.7
4000	3.8	2.0	0.0	1.1	6.9
7000	1.6	0.0	1.3	1.1	4.0
Average	2.4	1.2	0.4	0.8	

*Eight month average from April to November, 1971.
** Since index is based on 0 - 5 scale, total merely reflects relative abundance of all psyllids when comparing different elevations.

Progress report on soil and duff inhabiting arthropods and vertebrate ectoparasites

Introduction and Organization

This project was begun during the first grant year but was not funded until the second year (beginning September 1, 1971). Although considerable preliminary work and organization was carried out during the first year, more intensive research was delayed until near the beginning of the second year.

It should be reemphasized that the scope and title of this project has been extensively modified from that given in the initial application for the Subprogram. Originally, the objective was to investigate parasites of vertebrates, and there was then no specific research plan for integrating the work with the Subprogram as a whole. As reflected in the last report, the current report, and the new title, the project now has equal or greater emphasis on studies of arthropods found in soil and litter (and surface or subsurface substrates generally). Both the substrate fauna and ectoparasite sections of the project are closely integrated with the Subprogram, in terms of collaboration and objectives.

Personnel currently involved in the project in a direct way, other than cooperating systematic specialists, are as follows:

Frank J. Radovsky	-	Principal Investigator
P. Quentin Tomich	-	Mammalogist, joint project on mammals and ectoparasites
Gordon Wallace	-	Medical Zoologist, toxoplasmosis in mammals and other potential hosts
JoAnn Tenorio	-	Research Associate, all aspects of project
G. A. Samuelson	-	Research Associate, sampling methods and survey of soil and litter macrofauna
Francis Howarth	-	Research Associate, cavernicolous fauna
J. Jacobi	-	Field Assistant (also currently Field Technician for Subprogram)
Bruce Dalton	-	Field Assistant, mammal and ectoparasite collection
Various technicians at Bishop Museum	-	Preliminary sorting, slide-mounting, etc.

A. Soil and Duff

1. Field studies and collections

(a) Collections for Berlese extraction have been made at regular intervals throughout the present year; in July they were started and have since been continued on a quantitative basis. Quantitation is based on surface area (0.05 m^2) and (grossly) on horizon; 2 samples are normally taken (1) the loose surface litter containing whole leaves and other relatively intact plant material of parts thereof, and (2) the underlying humus and/or mineral soil to a depth of approximately 2 centimeters.

Collections have been made (1) at major relevés and some other relevés and other points on or near transect 1 (a few other collections elsewhere on the island of Hawaii and in the Leeward Chain); (2) in association with the pitfall trap collections (see below); (3) from fumaroles (see below); (4) from lava tubes (see below). A total of approximately 475 Berlese samples have been extracted and sorted to date.

Initially Berlese extraction was done by natural drying, in order to maximize the number of organisms recovered. For quantitative sampling, we are using the more typical Berlese (Tullgren) funnel with a closed top and a built-in source of heat and light. Although a few additional organisms may be lost in this way, the effects of atmospheric variables are essentially eliminated and comparability of samples increased. A total of 25 funnels with identical design has been obtained; 15 are now at the field laboratory in Hawaii Volcanoes National Park, so that extraction can be conducted without the delay of storage and transportation to Honolulu.

(b) Pitfall traps were designed and fabricated suitable for use under the edaphic and climatic conditions in Hawaii. The basic design is that of Fichter (1941, Ecology 22: 338-339). Each trap consists of a plastic cylinder; a shelf sealed to the inside of the cylinder about 6 inches below the top, angled to drain to the sides, provided with peripheral fine-screened areas for drainage, a central opening (for funnel), and 4 vertical flanges to lead arthropods into the opening; a funnel with bottom screw-on attachment for collecting jar; and a roof suspended over the funnel opening. The trap is installed in a hole so that the top is flush with the ground surface. Fourteen of these traps were put in the field in June and July 1971: 12 at locations from 3500 to 8000 feet on transect 1 (largely corresponding to principal releves and including one near Mauna Loa Strip Road weather station) and 2 in the Kilauea Forest Reserve.

The traps have proven to be an efficient and meaningful sampling technique in the way in which we are using them. Soil zoologists have pointed to the limitations of pitfall traps due to bias from location and from the effect of species behavior on the likelihood of particular animal species entering the traps. We have attempted to avoid bias from location by situating the traps away from tree trunks, fallen logs, etc. that would influence direction of movement. A control is provided in regular sampling for Berlese extraction in the general vicinity of traps. For comparison of dominant species in different locations and through the year, the traps should provide useful data. A number of organisms, such as some beetles and sow bugs, as well as some of the smaller forms, are regularly collected in the traps but not in Berlese samples.

Picric acid has been used in pitfall traps by some workers, because of the possible repellancy of alcohol and other fixatives. Picric acid does not provide adequate fixation and preservation for some arthropods. Therefore we are alternating the use of alcohol and picric acid in each trap.

More than 120 samples from the pitfall traps have been sorted to this time.

(c) Fumarole collections were continued in 1971. Two of the larger and more typical fumaroles were mapped, and surface and sectional scale illustrations prepared. A string grid was put over the opening, and substrate samples and temperatures were taken together, at one foot intervals. Temperatures were measured with a telethermometer, and included both surface and subsurface temperatures in order to bracket as closely as possible the conditions in which collected arthropods were living. Berlese extractions were made of 129 samples; in the grid study these were standerdized as 4" X 4" X 1/2" deep samples whereever feasible.

No arthropods were obtained from samples taken closest to the vents emitting steam, where sample temperatures were 70°C and above. Collembola were obtained at sample temperatures as high as 65°C. A variety of arthropods are tolerant of moderately high temperatures; e.g., a sample with a minimum temperature of 42°C yielded Diptera (larval Nematocera), Collembola, Prostigmata, and Cryptostigmata. Analyses of arthropod species, temperature tolerances and vegetational association within the fumaroles are in progress.

(d) Cavernicolous fauna. F. Howarth (Bishop Museum) initiated studies of arthropods associated with lava tubes in the spring and summer of 1971. This has proven to be an extremely fruitful project and the preliminary results summarized in another section of this report are in press and will appear in an early issue of Science (Contribution No. 1, Island Ecosystems IRP/IBP Hawaii). Because of similarity in objectives and techniques, the study has been integrated with this project to a certain extent. Thus, we are including soil and pitfall samples from lava tubes in the respective numbered series for this project, and, where practical, specimens requiring the attention of other systematic specialists are being sent to the same workers. The latter avoids the possibility that 2 or more specialists might publish descriptions of the same new taxa.

(e) G. A. Samuelson (Bishop Museum) has been supported by the project for studies on soil macrofauna. Thus far, he has spent 7 days in the area of transect 1, experimenting with ground cloths, sieving, baiting and other methods. This is primarily directed at recovery of Coleoptera and other insects that may be present in significant numbers but not be taken in Berlese sampling or pitfall traps.

(f) Dr. Taiji Imamura (Department of Biology, Ibaraki University, Mito, Japan), a leading specialist on aquatic and sub-aquatic mites (recently elected as one of four Honary Members of the International Congress of Acarology) spent 30 days in Hawaii surveying the aquatic acarine fauna of the major islands (Sept. - Oct. 1971). As anticipated, the fauna is depauperate, but several new species (as well as new records) were discovered and the results of the survey will be published with acknowledgment of IBP support. Dr. Imamura was provided with expenses for inter-island travel and per diem during his visit; his fare to and from Hawaii was provided by other sources. His work is justified as part of this project because of the potential findings relative to insular biotic evolution and the intergradation between terrestrial and aquatic faunas.

2. Processing and identification

Cooperation has been obtained in identification of all the major groups of arthropods present in collected samples.

Acarina	- Cryptostigmata	- H. Sengbusch
	- Mesostigmata	- F. J. Radovsky, J. M. Tenorio
	- Prostigmata	- R. W. Strandtmann
Araneae		- L. J. Pinter
Crustacea	- Isopoda	- G. A. Schultz
Insecta	- Collembola	- P. F. Bellinger
	- Hemiptera	- W. Gagné
	- Thysanoptera	- F. Bianchi
	- Diptera	- J. M. Tenorio, W. A. Steffan, M. Delfinado
	- Coleoptera	- G. A. Samuelson
	- Hymenoptera (ants)	- E. Huddleston

Some groups, such as Dermaptera, respresented by one or a few well characterized species, are routinely identified without consultation with systematic specialists.

Progress in identification of the various groups is, of course, irregular. Preliminary sorting and counting to order, suborder, and sometimes family has been placed on a routine basis and is being kept up to date. Most progress has been made in specific identification in the Mesostigmata among the mites and the Collembola, Thysanoptera, Dermaptera, Hemiptera, and Diptera among the insects. A major objective with the larger groups is to obtain identified material of the commoner species that will permit us to identify and count them in this laboratory. This has been best achieved for the Collembola (through the generous cooperation of Dr. Bellinger); species identifications (or reference to new or questionably identified species) are being kept up to date for all Collembola being collected. We anticipate similar progress for all major groups by the end of the current grant year.

3. Data processing, interpretation and publication

Unlike the second part of this project involving ectoparasites, we are not yet at a stage where data on soil arthropods can be integrated with the general program. This is largely a result of the complexity of the fauna and the mass of data that must be treated. We will start computerization of data during the spring of 1972. Some interpretation could be made from data at this stage and in its present form; however, this would necessarily be tentative and will not be attempted in this report. A first manuscript for publication of the initial results of these studies may be prepared in the fall of 1972. A preliminary interaction diagram for the soil and litter fauna is appended.

B. Ectoparasites

1. Small mammals

Trapping of mammals and survey of their ectoparasites was started early in 1970 as indicated in the previous report. Quantitative studies in collaboration with Dr. P. Q. Tomich were initiated in April 1971. Trap-lines are in operation on the 4 transects within the Kilauea Forest Reserve; this area is the location of the major intensive study on small mammals, their behavior and interaction with environment, seasonal variations, and the relation of ectoparasite load to other factors. Two transects are run each month (so that any one transect is trapped at bimonthly intervals): one a trap-release line (with 60 traps) and the other for capture and removal of rodents to the laboratory (with 60 traps). In addition to the mammalogical processing, standard procedures are used for washing of all animals brought to the laboratory for parasite recovery. Parasites are preserved in alcohol, slide-mounted at the Bishop Museum, and identified.

Operation of 9 selected sites on transect 1 was started in October 1971. These will provide comparative date on mammals and their ectoparasites from 3000 to 7000 feet, and in different vegetational associations. At each site 39 traps will be operated; since each site will be trapped only 4 times annually, all captured animals can be removed without decimating the populations or requiring a control trap-release line.

A separate summary by Dr. Tomich, including mammalogical observations, is given in this report (D2).

All data for hosts and ectoparasites is directly coded on field sheets (ectoparasite identification and counts, stomach content analysis, etc. added in the laboratory) so that the information can be computerized from these sheets. The first input of data to Dr. Mi's system was in August 1971.

Analysis of ectoparasite trends as well as mammalogical data by location and season will require longer runs for all trap lines. Some features are obvious now. *Rattus rattus* is the dominant rodent species in Kilauea Forest Reserve. *Ornithonyssus bacoti* is a common parasite of *R. rattus* at low elevations (previous studies and some miscellaneous collections in this study), but it does not occur in the Forest Reserve and has not yet been taken at other higher altitude locations in this series. Additional data on this and other species should shed light on the parameters limiting the distribution of various parasites.

The ectoparasites known from small mammal hosts in Hawaii include 7 species of fleas, 2 species of lice, and more than 17 species of mites. All identifications are done in this laboratory; most of the known species have been identified in some of our collections. Three species of *Hypoaspis* (Acarina: Mesostigmata) have been found that were not previously known in Hawaii: *H. nidicorva*, *H. sardoa*, and *H.* sp. near *aculeifer* (possibly new species). *Hypoaspis* species are frequent nest inhabitants but are generally considered to be non-parasitic.

One or more manuscripts on Hawaiian mammals and their ectoparasites should be completed in 1973. A note on some ectoparasite collections in the northwestern (leeward) islands has already appeared (see below).

As a routine part of our collecting operation, 2 blood discs are made for each host. These are subjected to serological analysis in Dr. Wallace's laboratory, primarily for studies on the epidemiology of toxoplasmosis. Dr. Tomich is inoculating culture medium with kidney material for leptospirosis survey.

2. Avian hosts

Approximately 45 avian hosts have been examined for ectoparasites in 1971. Most of these are introduced birds, including Barred Dove, Speckled Dove, Barn Owl, White-eye, House Sparrow, and House Finch. Native birds examined include the Amakihi and Apapane. Ectoparasites from these hosts have been mounted and prepared for study. This will provide information on the degree of interchange of ectoparasites between native and introduced birds, as well as the parasites of each group. When this survey was initiated in 1970, the blood-sucking cheyletid mite, _Bakericheyla chanayi_, was recorded from Hawaii for the first time, with a new host record on the Shama Thrush (_Proc_. _Haw_. _Ent_. _Soc_., in press).

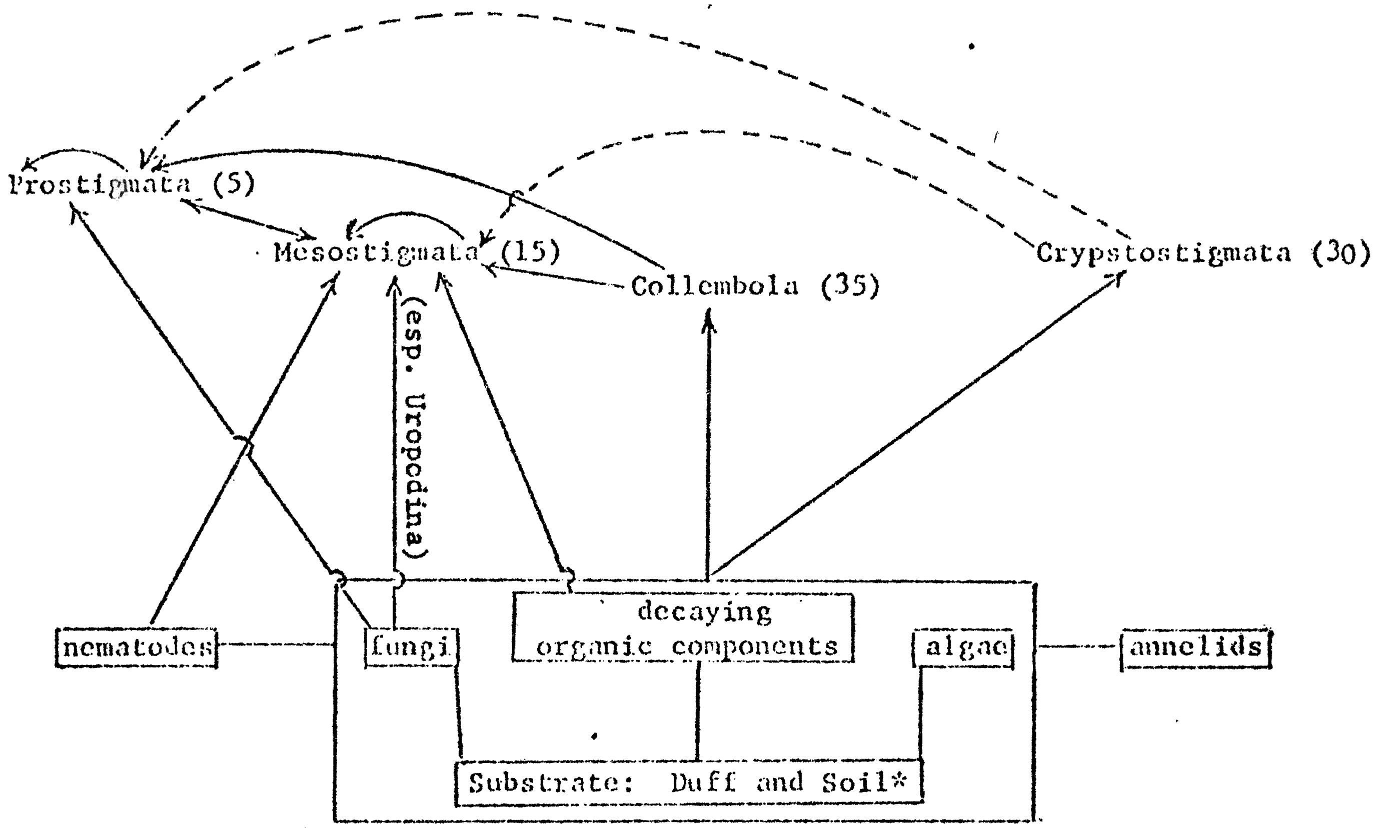
Publications:

A note giving new records of chiggers from the Northwestern Hawaiian Islands was based on studies supported in part under this project. Another paper is being prepared on ectoparasites from the "Leeward Islands."

M. L. Goff. 1971. New records of chiggers (Acarina, Trombiculidae) from the Northwestern Hawaiian Islands. _Jour_. _Med_. _Entomol_. 8(4): 456.

IBP Hawaii Subprogram: Island Ecosystem Stability and Evolution
Contribution to Ecosystem Model for Transect Study

Interactions of Major Biotic Components in the Soil Habitat
with Particular Reference to the Arthropod Fauna**
(a preliminary analysis)



* Primarily mor-type humus in forests at lower and intermediate elevations providing the greatest variety and numbers of macrofauna.

** Numbers after each arthropod group in the diagram represent approximate percentages of individuals in total arthropod fauna collected on sites along transect thus far. The 4 named orders constitute 85% of the total fauna, with Collembola and Cryptostigmata as the major primary consumers. (Cryptostigmata are particularly important in bringing about breakdown of plant material, both directly and through spread of microorganisms.) The other 15% is made up of a variety of arthropods, each constituting less than 2% of the total number, including Hymenoptera - ants (2), Thysanoptera (2), Homoptera (2), Coleoptera (1-2), Dermaptera (1), Diptera (1). Of these, the ants and beetles may be particularly important as predators and as scavengers on animal remains.

The soil habitat overlaps with others. Many of the same species of mites may occur in the soil and on the trunks of trees in moist forest situations.

The extent of predation on heavily armored Cryptostigmata by other mites requires further study; it may be most significant in its effect on the immature stages and on less sclerotized species -- hence the broken lines leading from Cryptostigmata.

The Collembola and Cryptostigmata, as groups, feed to a significant extent as saprophages, fungivores, and algivores.

Pitfall Traps on East Slope of Mauna Loa
(Hawaii IBP, Project C-9, Soil and Litter Arthropod)

Reference Number	Releve No. or other location	Elevation (ft.)	Sampling Interval
1	11	8000	monthly
2	15	7500-7600	monthly
3	16	7000	monthly
4	17	6500±	every 2 weeks
5	24	6200	every 2 weeks
6	76	5200±	every 2 weeks
7	21	5200	every 2 weeks
8	40	4200-4400	every 2 weeks
9	Kipuka Ki Weather Station	4100	every 2 weeks
10	19	4000±	every 2 weeks
11	38	4000+	every 2 weeks
12	18	3500±	every 2 weeks
13	Kilauea Forest Reserve (nr. rain gauges 9-11)	5600	every 2 weeks
14	Kilauea Forest Reserve (nr. malaise trap on transect 1) (110m from base of transect)	5600	every 2 weeks

C-9 (continued)
F. J. Radovsky
F. G. Howarth

Progress report on

Cavernicoles in Lava Tubes on the Hawaiian Islands

The discovery of a native component of the Hawaiian fauna adapted to living in lava tubes was made on an I.B.P. field trip in July, 1971. Subsequent field trips have shown the fauna to be a unique one and of significant potential for ecological and evolutionary research. Because of the simplified ecosystem, caves have been used in continental regions as ecological laboratories. Also, the remarkable adaptations of cavernicoles have made them favorite animals for evolutionary biologists. Therefore, the discovery of troglobites (obligatory cavernicoles) in caves on an oceanic island offers tremendous potential for the goals of I.B.P. A preliminary report of these discoveries is being published in Science.

Progress to date on the cave studies shows that the variety of organisms that have become cavernicolous is remarkable, as the cave ecosystem has been invaded by the elements of the disharmonic Hawaiian fauna. These, in many instances, are not related to the cave fauna of the continental regions. The study has already shown the fauna to be not as disharmonic as it was presumed to be. Two new family-groups not previously recognized in the native fauna have been discovered. Are these relics of an earlier fauna? A preliminary list of cavernicoles is appended to this report.

Most troglobites are known from temperate regions south of the maximum glacier advances, and are mostly relics with no close epigean relatives. The few previously known tropical troglobites are aquatic, apparently relics of former sea levels. This has led to the hypothesis that troglobites evolved after their epigean relatives became extinct as during glaciation. The small populations isolated in caves survived and evolved to specialized cave organisms unable to survive on the surface (T. C. Barr, 1968 Evolutionary Biology Vol. 2, 35-102).

Island evolutionary biologists, on the contrary, have hypothesized a founder principle whereby, when a small population, even a single fertile female, becomes established on a new substrate it differentiates, sometimes very rapidly, into a separate species from its progenitor. The explosive adaptive radiation on oceanic islands seems to show that speciation can occur on a single island with the only physical barrier being a switch of host plants by a population of a species. The exciting discovery of a troglobitic fauna on an oceanic island known for its remarkable examples of adaptive radiation offers unparalleled possibilities. Now, for the first time, these two theories might be reconciled, if indeed they are different.

I propose to survey the fauna of Hawaiian lava tubes and to study the ecology of this simplified ecosystem and the evolution of its organisms. Because of the overlap this survey is being coordinated with the I.B.P. soil arthropod fauna studies of Dr. F. J. Radovsky. As many different caves as possible will be surveyed from sea level to the moss desert. Notes will be taken on physical parameters of the cave and biological correlations between organisms to get their distribution, rates of dispersal, dispersal mechanisms, and biotic interactions. After the initial survey has shown what organisms are important in the ecosystem, sampling methods will be devised to check population sizes, arthropod-arthropod interactions, and prey-predator interactions. A food web for the caves can then be constructed. Preliminary observations have shown that the number of organisms counted in a unit length of time, an hour or more, is related to the population size. This technique, and various types of traps and markings, can be standardized to estimate populations.

The study will show what types of caves are significant for troglobitic evolution and will lead to hypotheses on the factors in and rate of evolution of troglobites, which may be quite significant.

I would like to initiate studies on the slime fluxes within caves. It is hypothesized now that these may be chemoautotrophic bacteria breaking down the lava and providing food for some of the cavernicolous arthropods. Also, many of the lava tubes have little overburden and tree roots form the major component of the biomass. These subterranean "aerial roots" offer a significant opportunity to botanists to study the transport systems and phenology of tree roots. At least on the newer lava flows on the Mauna Loa and Kilauea massifs, it is assumed that these roots are little modified from those penetrating cracks in the lava, so that one can study the root systems of a tree in situ without disturbing the plant. This offers as yet untapped potential for research on root systems. These are studies which I am not qualified to really initiate. However, I will be very willing to aid other specialists wanting to work on these.

Publications:

F. G. Howarth, Cavernicoles in Lava Tubes on the Island of Hawaii, Science, In press, (Contribution No. 1 Hawaii IRP/IBP).

Appendix

Cavernicoles from Hawaii and Kauai:

- Thysanura--Nicoletia meinerti
- Orthoptera--Gryllidae
  - Thaumatogryllus new species
  - Nemobiinae? unknown genus and species
- Hemiptera--Mesoveliidae--2 new species, one troglobitic
- Homoptera--Cixiidae--1 new species, troglobitic
- Coleoptera--Carabidae--Tachys arcanicola
- Araneida--Lycosidae?!--2 new species, one troglobitic, one perhaps so
- Amphipoda--1 new species, troglobitic?

I also have collected species of Isopoda, Collembola, and Acarina which show some modification but have not yet been identified. Myriapoda, Diptera, Lepidoptera, and other representatives of the above groups, probably all surface species, make up most of the remaining collections.

Progress report on effects of diseases of insects in Hawaiian ecosystems.

Minoru Tamashiro
Michael Conant

Uresiphita polygonalis is the principal herbivore, aside from goats, on Mamane. The larvae of this moth periodically reach population levels which nearly defoliate entire trees of Mamane, its principal host plant.

Damage by U. polygonalis is indicated by leaves and stems webbed together. Damage characteristic of the first two instars and often the early part of the third is small areas of surface feeding on the leaves within the webbing. During the last part of the third instar and during later larval instars the leaves and stems within the webbing are either partly eaten or entirely consumed. The larvae are gregarious and up to forty-six first instar larvae, probably from the same egg mass, have been collected between the webbed leaves of only two stems. The webbing usually contains the sawdust-like fecal pellets.

Uresiphita polygonalis was first collected in Hawaii on Haleakala by Blackburn before 1881. It has since been collected on Oahu, Kauai, and Hawaii (Zimmerman, 1958).

The highest populations of this insect occur between 4,000 to 6,000 feet in open, dry forests composed of Koa, Mamane and Naio, or just Mamane. The adult flies readily during the day and has been observed feeding on the nectar of grass flowers.

The adult moths have a wingspread of about thirty millimeters. There is considerable variation in wing color and pattern.

U. polygonalis develop, mate and lay eggs in the lab, so there is a constant supply of insects for the study. Development from egg to adult takes about fifty days at twenty-three degrees centigrade with the larvae feeding on Mamane leaves.

The female moths usually lay their eggs in groups of about thirty on either side of the leaf. Total number of eggs laid per female will be determined. The eggs hatch in four days and the first instar larvae emerge measuring two millimeters long. The larva molts six times. The first four of the six instars last four days each; the fifth stage lasts five to six days and the sixth stage eleven to twelve days. At the end of the sixth and last larval stage the full grown larvae, now measuring twenty-eight millimeters long, moves from the leaves to the ground, changes color, spins a silken cocoon under rocks or leaf litter, and pupates. The pupal stage lasts for fourteen days and then the adult moth emerges from the brown pupal case. The larval coloration and markings vary in different instars; the first instar larvae have a black head capsule and no lateral markings. Later larval instars have brown head capsules and black and yellow, longitudinal, lateral stripes until the later part of the last larval instar when the larvae change color from green to brown and lose the lateral yellow stripe.

An artificial diet for raising the larvae aids in standardizing results and is more practical in food handling. Zimmerman (1958) states in England the moth feeds upon Genista, Cystisus and on legumes. Two agar base legume diets, Harley's diet and Pinto Bean diet, have been tried but development is slower and pupal and adult sizes are smaller than the field-collected pupae and adults. A lima bean diet will be tested, but results thus far indicate a modification of one of these diets will be best, substituting blended Mamane leaves for part of the standard legume portion.

In the lab the adults are fed a one-third honey and two-thirds water solution.

Zimmerman (1958) quotes Perkins (1913: clx): "These caterpillars also eat the leaves of Acacia koa...". Host suitability tests of Koa are being conducted and development on Koa, if it occurs, will be compared to that on Mamane. To date no IBP workers have observed the larvae or eggs on phyllodes or juvenile leaves of Koa.

Periodic sampling of Mamane are made at selected sites:

a. Mauna Loa Strip Road - 4,300 feet
b. Mauna Loa Strip Road - 5,000 feet
c. Mauna Loa Strip Road - 6,700 feet
d. Pohakuloa - 6,400 feet
e. Saddle Road (near Kilohana) - 5,300 feet

Foliage is taken from each of ten trees in each area, giving ten samples per area. Sites are sampled once a month during periods of low population and twice a month during periods of high population. Late instars are easily shaken from the tree so the same trees are not utilized for each sampling to insure sampling techniques don't affect the population of the insects sampled.

The samples are taken back to the lab to obtain the number of insects per leaf surface area. The leaf surface area is obtained by drying the leaves in an oven. The dry weight of the leaves is converted to surface area in an equation using predetermined surface area per dry leaf weight known for that location. This ratio is compared with previous sampling ratios to determine if the population is increasing or decreasing.

Initial samples were taken July 3, 1971. Those and subsequent counts show that at 4,300 and 5,000 feet on Mauna Loa the population had previously peaked. The decline at the two elevations continued through mid July and the population sharply decreased in late July. From the end of July until the time of this report, the populations at these two sites are only evidenced by an occasional egg mass, larva or adult sighting. U. polygonalis remains present at these elevations during this time in very low populations.

At 6,700 feet on Mauna Loa on July 3, 1971 the population appeared to be at its peak. Although there were no previous figures for the comparison, observations were made before sampling techniques were developed.

Observations at 6,700 feet:

a) Before June 15, 1971, no adults, eggs larvae or larval damage was observed at 6,700 feet.

b) On June 15 several adults were observed. Larvae present were early instars, first and second; and damage was slight, small areas of surface feeding characteristic of early instars.

c) On July 3, adults were more numerous than on June 15. All stages of larval development were observed, although early instars were predominant. Webbing was more evident than before. Both types of feeding damage were present, small areas of surface feeding, and stems with leaves in part or entirely eaten.

Counts at 6,700 feet on Mauna Loa on and after July 17 show the population at this location sharply drops off. Adults sighted were few. The numbers of eggs and larvae seen and collected on and after July 19 indicate the population is present in vary low numbers up to early October. After October 3 there were no indications of U. polygonalis at 6,700 feet.

Population decline at the other sites is similar to that on Mauna Loa, the sharp decrease near Kilohana occurring two weeks later.

The factor or factors effecting this sharp decline should be categorized and evaluated. On Mauna Loa parasitism exerts partial control. Insects collected in the field are reared in the lab for incidence of parasitism. Two egg masses out of seven collected were parasitized by a Trichogramma sp. and no larvae hatched. Death from parasitism by Dipteran and Hymenopteran parasites varied from twenty-three to thirty-five percent, averaging twenty-nine and a half percent.

The populations or part of them may be moving to lower elevations. Larvae have been collected at 1,900 feet on Mamane near Hualalai between Puuanahulu and Huehue Ranch. At lower elevations the population could maintain itself on other host plants, e.g., as it does on legumes in England. Zimmerman (1958) quotes Perkins (1913: clx): "...and the moth sometimes occurs in places where no Sophora grows...". More observations must be made at lower sites.

Another answer to the decline could be diapause, to escape unfavorable conditions. To investigate this, a bioclimatic cabinet will be used to subject the insect to varying conditions of light and temperature to see if these factors can cause diapause in this insect. The bioclimatic cabinet available can't control relative humidity; it would be interesting to investigate the effects of varying humidity. Rainfall values at 5,400 and 5,600 feet show a yearly low in June, just before the population decline.

Charles Lamoureux is studying the phenology of Mamane and the population fluctuations of U. polygonalis will be examined for relationships with his results. To date it appears the two are not related. There was no increase in insect number during October and November, two months when Mamane showed increases in budding and growth.

In the Kilohana area on Saddle Road there is a virus disease that periodically decimates high populations of the larvae. Here the disease is a major factor exerting control on larval populations during times when these are high. Up to eighty-six percent of larvae collected from this area, brought back and reared in the lab under crowded conditions, have died from this disease.

The virus is a nuclear polyhedrosis virus characterized by cuboidal shaped polyhedra.

The virus disintegrates the epidermis and most of the internal tissues of the larva, virtually liquifying the insect in a cuticular sack. When the cuticle is ruptured the polyhedra spill out and are scattered to other parts of the tree where they can be eaten by other larvae, spreading the disease.

Larvae that died in the lab and dead larvae collected from the field were pulverized and this mass was filtered, then centerfuged. The polyhedra settled as a white layer. This layer was used as an innoculum. Ten virus-free larvae were fed leaves dipped into the innoculum and ten control larvae were fed leaves dipped into distilled water. The larvae fed the polyhedra died, the control larvae developed through to adults. Slides made of the ten dead larvae showed all larvae were loaded with polyhedra. The innoculum will be used for a series of tests and dilutions to determine the virulence of the virus.

Larvae dying from this disease first show signs of delayed development, the time taken by the larvae to go through an instar is increased. The diseased larvae are smaller than healthy larvae or the same age. As the disease progresses the larvae become sluggish and no longer eat. They develop a shiny, white color beneath the integument from the masses of polyhedra present. Finally the larvae become a fragile sack, break open, and their contents flow out. Often the larvae will climb then die hanging by their prolegs, spreading the disease over a relatively large area.

This disease has only been recovered from the Kilohana area on the Saddle Road and not on Mauna Loa. At Kilohana the ecosystem is simple, composed mostly of open pasture land with low grasses and scattered Mamane trees. This area is overcast much of the time, increasing chances of virus survival by reducing exposure to the lethal rays of the sun.

Zimmerman, E. 1958. Insects of Hawaii, Univ. of HI Press, Honolulu, Vol. 8: 115-118.

Progress Report 1970-1971, Evolution of Hawaiian Honeycreepers

A. J. Berger

This report includes progress statements on the two primary facets of the research on the endemic Hawaiian honeycreepers.

1. Comparative functional anatomical studies:

This long-term study was initiated in 1966, and was supported, in part, for three years by NSF Grant GB-5612. It has been supported since 1970 by the present grant.

a. Robert J. Raikow, an N.I.H. postdoctoral fellow, joined me in 1970 to work on a study of the "Anatomy and Evolution of the Hawaiian Honeycreepers." Raikow accompanied me in the field on Hawaii for the period January 11-14, 1971 in order to have the opportunity to observe both the nectar-feeding and seed-eating honeycreepers in their native habitat. These observations were made in the endemic ohia-tree fern ecosystem (Volcanoes National Park and the Kilauea Forest Reserve) and in the mamane-naio ecosystem (on Mauna Kea). Raikow later also made one trip to Kauai in order to observe at first-hand the behavior of certain species of honeycreepers that are confined to that island. This field experience complemented the observations on feeding and locomotor behavior that he was able to make on the several species of captive honeycreepers in my laboratory.

Raikow proved to be an exceptionally well-trained zoologist, who gives every promise of becoming an outstanding scholar in the field of avian and comparative anatomy with special reference to the functional and evolutionary interpretation of morphological data. The complexities of the problem he undertook were such that he could not possibly have completed the research in one year, and, even though he was awarded the N.I.H. fellowship for a second year, I agreed with him that his only sensible decision was to decline the fellowship and accept a permanent-type position in the Zoology Department of the University of Pittsburgh, effective in September 1971. Dr. Raikow has taken all necessary anatomical material with him, and will continue the research in his new position. By the end of 1972, he should be in a position to begin to publish significant contributions of interest to ornithologists, anatomists, and taxonomists; his findings will be essential to my goal of attempting to clarify the taxonomy and evolution of the honeycreepers.

b. Dr. Richard E. MacMillen (University of California, Irvine) spent July and August 1971 in the laboratories of the Department of Physiology of the Manoa Campus of the University of Hawaii, where he received the full cooperation of Professor Causey Whittow. MacMillen conducted thermoregulatory studies on several species of primarily nectar-feeding honeycreepers from my aviaries. MacMillen has had extensive experience in such research both in North America and Australia. The report on his work on the honeycreepers is presented under Subproject D-3.

MacMillen plans to return to Honolulu during the summer of 1972 in order to broaden the scope of his work to include a physiological study of some of the finch-billed honeycreepers. The data he obtains obviously will be of significance to an understanding of the physiological adaptations of the honeycreepers to the Hawaiian ecosystems in which they evolved.

It is my feeling that I could not have found two more competent collaborators than MacMillen and Raikow for this aspect of the research.

c. Dr. Walter Bock (Columbia University) is continuing his studies of jaw morphology and evolution of the American nine-primaried passerines, which includes the Hawaiian Drepanididae. The anatomical studies of Bock, Raikow, and myself are complementary, and we will share anatomical material, especially of those species that are now classified as rare and endangered.

2. Ecological and biological studies:

I collected data on the distribution and numbers of species found in the transects (from above tree line to sea level) on Mauna Loa and Mauna Kea, as well as in the Kilauea Forest Reserve and the Laupahoehoe Forest Reserve. The latter two areas represent near-virgin ohia-tree fern forests, and are, therefore, of special importance in a study of the honeycreepers. I have obtained considerable circumstantial evidence that introduced rats prey on the eggs, young, and adults of nesting honeycreepers. I worked in both of the forest reserves with Dr. P. Quentin Tomich because of our mutual interest in finding reliable methods for determining the interrelationships of the birds to both rats and pigs. Tomich and I also spent one day in the Kilauea Forest Reserve with Dr. Gordon Wallace of the U. S. Public Health Service, who was especially interested in assessing the feasibility of obtaining information on viral diseases carried by the rodents and pigs.

I spent four days in the Laupahoehoe Forest Reserve on the slopes of Mauna Kea with David H. Woodside and John Giffin of the State Division of Fish and Game. Giffin has been studying pig populations on Hawaii for over a year, and will assist in our work in the Kilauea Forest Reserve during the coming months. The lower portion of the Forest Reserve remains in a near-virgin condition and is excellent habitat for endemic birds. The upper portion, however, has a serious infestation of banana poka, and Giffin reported that this forest supports the highest density of pigs that he has yet found on Hawaii. The destruction of ground cover and seedlings by the pigs was conspicuous throughout the forest.

On July 8-9, 1971, I served as host to introduce Dr. G. P. Baerends (Director of the Zoological Institute of the University of Gronigen, Netherlands) and his wife to the mamane-naio and the ohia-tree fern ecosystems on Mauna Kea.

Dr. George Barlow (University of California, Los Angeles) joined us on July 9.

I joined Dr. Lin Gressitt, Dr. Elmo Hardy, and Mr. Wayne Gagne on a two-day field trip to Molokai in mid-July. Our guide was Mr. Noah Pekelo, of the State Division of Fish and Game on Molokai, who is very knowledgeable about the ecology of the island. We hiked the trail to Puukolekole one day, and visited the Molokai Forest Reserve the following day. Each of us had multiple reasons for this special field trip. Gressitt is the Chairman of the Governor's Natural Areas Reserve Commission, and I am the Acting Chairman of the Governor's Animal Species Advisory Commission; Hardy and Gagne are active in the work of both Commissions. Each of us also was interested in our joint efforts in collecting data on the ecosystems we visited, and we were impressed by seeing the great damage done by feral goats in the drier regions of the island.

Dr. C. Robert Eddinger completed all requirements for his degree in 1970. His doctoral dissertation was entitled "The Breeding Biology of Four Species of Hawaiian Honeycreepers (Drepanididae)." Eddinger has now submitted his significant paper for publication.

I completed a six-year term as Chairman of the Department of Zoology as of June 30, 1971, and will be on sabbatical leave for eight months, beginning January 1, 1972. Nearly all of my time will then be devoted to the research on the endemic Hawaiian birds and their interrelationships with the ecosystems they inhabit.

Progress Report: Small mammals of Kilauea Forest Reserve, October 8, 1971

P.Q. Tomich

Trapping for small mammals began in April 1971. On Transect I are 60 traps spaced at 15 m intervals. Forty are cage-style traps designed for rats and mice, and they will capture an occasional mongoose. Twenty (every third trap in the line) are standard rat snap traps. All traps are baited with squares of fresh coconut. Snap traps are employed to capture rodents for a study of food habits of those killed at the moment of capture. All animals caught on Transect I are removed to the laboratory for collection of ectoparasites (Dr. Radovsky's interest) and biological data. None is returned to the forest.

Transect II has 40 cage traps arranged and operated like those on Transect I, and every third trap in the line is a heavy-duty mongoose live trap instead of a rat snap trap, so there are also 60 traps in all. Mongoose traps are baited with meat trimmings, mostly tallow. All animals taken on Transect II are released at the site of capture after marking with ear tags (rodents) or toe-clipping (mongooses). We also weigh each animal, determine sex and take other biological data.

The trap lines on Transects III and IV, respectively, replicate those on I and II. Each of the four lines is operated for three consecutive days, on a bimonthly schedule - Transects I and II in one month and Transects III and IV in the next. Trails connecting these pairs of transects near their far ends are marked to facilitate working the trap lines. Candy stripe is the distinctive tape for the small mammal work.

Species composition in the first 100 captures was 87 Rattus rattus (roof rat), 6 Mus musculus (house mouse), 6 Herpestes auropunctatus (mongoose) and 1 R. norvegicus (Norway rat). With a total of 1800 trap nights we have caught about one small mammal to 17 traps set.

The roof rat and the mongoose are very much at home in the forest. Although the forest is soggy much of the time, abundant shelter is found beneath the large koa trees, whether standing or fallen. The prominent roof rat is not obviously controlled by the mongoose. Factors other than predation probably account for the observed scarcity of the house mouse and Norway rat, and the apparent absence of the Polynesian rat (R. exulans).

We need to concentrate our efforts on the effects on the forest ecosystem of the roof rat. Dr. Berger has found surprisingly abundant evidence of predation by rats on nests of endemic birds. Perhaps the remarkable thing is that the apapane, iiwi, amakihi, omao and elepaio are relatively common in the forest.

Our study of food preferences in the rodents has not advanced beyond the collection of stomach contents. Assistance is still needed here for their analysis. One thing that we have been seeing is that some rats have blue fore paws, stained from handling and eating the fruits of some shrub or tree. Cheirodendron may provide this sort of food. Phenology of the vegetation should be correlated with the seasonal feeding habits of the rodents.

We are gathering base-line data on diseases of public health importance for two co-operating agencies. The NIH Pacific Research Section (Dr. Gordon Wallace) is interested in the incidence of *Toxoplasma* and the State Health Department (my organization) wants to learn about *Leptospira* in the Kilauea Forest small mammal populations.

Beginning this month we will be trapping at 9 selected sites from 3,000 to 7,000 feet on the Mauna Loa Transect, at quarterly intervals.

Trapping periods at Kilauea Forest for the rest of the year are: October 21-24, November 18-21, and December 16-19.

Summary: Small mammal trapping April 1971 - November 1971

P. Quentin Tomich

A progress report dated October 8, 1971 outlines field and laboratory procedures for the small mammal sampling program.

Pooled data for Transects I-IV in Kilauea Forest Reserve (Table I) demonstrate the following species composition in 156 captures: Rattus rattus (roof rat) 83%, Herpestes auropunctatus (mongoose) 10%, Mus musculus (house mouse) 6%, and Rattus norvegicus (Norway rat) and Felis catus (feral cat) each less than 1%. One small mammal was captured for each 16 trap nights.

It is immediately obvious that the roof rat maintains a stable and moderately large population in the forest. Almost certainly it is the most important of the small mammals, and along with the feral pig it may have a profound influence on the character of the forest ecosystem.

The mongoose is also very much at home in the forest. Although the habitat is soggy much of the time, abundant shelter is found beneath the large koa trees, both standing and fallen. The roof rat is very obviously not decimated by the mongoose. Factors other than predation probably account for the scarcity of the house mouse and of the Norway rat, and for the apparent absence of the Polynesian rat (R. exulans).

We need to concentrate our efforts on the effects of the roof rat on the forest ecosystem. Dr. Berger has found surprisingly abundant evidence of predation by rats on the nests of endemic birds. Perhaps the remarkable thing is that the apapane, iiwi, amakihi, omao, elepaio and creeper are all relatively common in the forest.

Biological data on the small mammals are coded as collected and will be analyzed when programmed, by the end of the first year of field study, in June, 1972. We are particularly interested in defining the annual cycle of the roof rat through the parameters of age structure, seasonal density, reproductive patterns and rates of survival. Comparative studies are being made between communities of rats where trapped animals are removed and those where they are released.

Our study of food preferences includes the preservation of stomach contents of kill-trapped rats. Technical assistance for identification and quantification of food materials is being sought and support for this activity is to be proposed in the next budget. We have noted examples of rats eating the starchy core of Cibotium, sometimes extensively, and seasonally a blue staining of the forepaws of rats that apparently had eaten the fruits of Ilex. These and other observations will be correlated with phenological studies of the vegetation.

A second segment of the small mammals study includes 9 sites at relevés on the Mauna Loa Transect, from 3,000 to 7,000 feet elevation. Sampling began here in October, 1971 and is projected through December, 1972 when trapping will have been done quarterly for 117 trap nights at each of the nine sites. As in Kilauea Forest, this segment will provide materials for the study of ectoparasites by Dr. Radovsky in addition to biological studies of the small mammal hosts themselves. To date, with 234 trap nights, 20 Mus and 7 R. rattus have been taken on the Mauna Loa Transect.

We are gathering base-line data on diseases of public health importance for two cooperating agencies. The NIH Pacific Research Section (Dr. Wallace) is interested in the incidence of Toxoplasma in populations of small mammals isolated from human populations, and the State Health Department (my organization) is inquiring about possibility of Leptospira infection at higher elevations.

Dr. Wallace reports as follows on his results for Toxoplasma:

"To date we have received and tested sera from 59 Rattus rattus, three Mus musculus and one mongoose captured in the Kilauea Forest Reserve, and two R. rattus and five M. musculus captured on the Mauna Loa Transect. Of these, two R. rattus and the mongoose from Kilauea and two of the mice from Mauna Loa were positive. It is of interest that the three positive Kilauea animals were captured in the same general area, Lines I-8, I-41, and I-45. Also of interest was positive results in two of five mice. On Oahu, the prevalence of antibody in this species has been remarkably low."

The Waiakea Health Center of the State Health Department (Hilo) has cultured kidney tissue from 26 R. rattus from Kilauea Forest for evidence of leptospirosis (September-November). All specimens have been negative. Lowland populations of R. rattus in Hawaii are often 30 to 50 percent infected with Leptospira.

TABLE I

SUMMARY OF SMALL MAMMAL TRAPPING ON FOUR TRANSECTS IN KILAUEA FOREST (April-November, 1971)

Transect	I-II	I-II	III-IV	I-II	III-IV	I-II	III-IV	Total	%
Month	Apr	June	July	Aug	Sept	Oct	Nov		
Species & Number									
Mus	1	4	1	0	0	3	0	9	5.8
R. rattus	8	22	12	24	29	20	15	130	83.3
R. norvegicus	0	1	0	0	0	0	0	1	0.6
Herpestes	1	3	0	0	2	4	5	15	9.6
Felis	0	0	0	0	0	1	0	1	0.6
Total	10	30	13	24	31	28	20	156	99.9

Physiological ecology of some terrestrial Hawaiian birds and mammals.

R.E. MacMillen

The months of July and August 1971 were spent on the subproject working in the laboratory of Dr. G. Causey Whittow, Department of Physiology, School of Medicine, University of Hawaii. During this period of time complete measurements of oxygen consumption, pulmocutaneous water loss, and body temperature were made over a broad range of ambient temperatures (10-40°C) in the avian species (F. Drepanididae) Loxops parva (the anianiau, from Kauai) and Loxops virens (the amakihi, from Kauai and Hawaii). Both of these birds are inhabitants of the high forests (4,500 - 7,500 ft.) and differ markedly in body size: L. parva, ca. 10 g and L. virens, ca. 20 g.

Both species of birds, at least when well-fed and well-watered, are effective thermoregulators, and maintain a constant body temperature of about 40°C between an ambient range of 10 to 30°C. At and above 35°C both birds become hyperthermic: L. parva at an ambient temperature (T_A) of 38.3°C had a body temperature (T_B) of 41.7°C, L. virens at T_A = 39.4°C had T_B = 42.9°C. Such a hyperthermic response is not uncommon in small passerine birds.

In the relationship between oxygen consumption and T_A Loxops parva had a thermal neutral zone extending between T_A = 33.5 and 35°C, in L. virens thermal neutrality extended between T_A = 31 and 35°C. Basal metabolic rate in L. parva (3.22 ± SD 0.20 cm^3 O_2/g/hr at T_A = 32.5°C) was insignificantly lower than that of the larger L. virens (3.41 ± SD 0.34 $cm^3 O_2$/g/hr at T_A = 35°C), which is contrary to the general rule in passerine birds that basal metabolic rate is indirectly related to body size.

While metabolic rate increased markedly with decreasing T_A below thermal neutrality, the slopes of these functions (thermal conductance) differed markedly interspecifically with the smaller birds (L. parva) having considerably higher rates of heat exchange than the larger (L. virens). Regression lines fitted to relationships between oxygen consumption and T_A below thermal neutrality for L. parva and L. virens are described by the equations $X = 10.54 - 0.22\ y$ and $X = 6.71 - 0.11\ y$, respectively (where X is oxygen consumption in cm^3 O_2/g/hr and y is T_A in °C).

Perhaps the most unexpected response noted was the nearly complete intolerance of the larger species (L. virens) to elevated ambient temperatures. Of a sample of six L. virens subjected to T_A 39 - 40°C (their usual body temperature) for two hours, four birds ultimately perished; all of a sample four L. parva survived exposure to T_A = 38°C, but none were subjected to higher T_A. Under conditions of dry air, and apparently stressful high temperatures both species were capable of only moderate evaporative cooling, in spite of rather high levels of pulmocutaneous water loss. At T_A = 38.2°C, L. parva had rates of pulmocutaneous water loss of 45.9 per cent of body weight per day and 4.4 mg $H_2O/cm^3 O_2$; under these conditions only 53.2 per cent of the endogenous heat production was dissipated by evaporative cooling. In L. virens pulmocutaneous water loss rates were

59.8 per cent of body wt/day and 4.9 mg H_2O/cm^3O_2; 59.3 per cent of endogenous heat production was dissipated by evaporative cooling.

These data reveal that in general the anianiau (*L. parva*) and the amakihi (*L. virens*) conform to the usual avian patterns of thermoregulation and bioenergetics in their responses to the environmental temperatures normally encountered in their high forest habitats (0-35°C). However, their basal metabolic rates are unusual in that they are approximately the same in birds differing in size by a factor of two; normally the smaller (*L. parva*) would be expected to have a much higher metabolic rate than the larger (*L. virens*). In addition, *L. virens* is unusually intolerant of high ambient temperatures (39°C) which are normally well within the ranges of tolerance of mainland passerine birds.

It is concluded that insular evolution of these drepanidids has resulted in certain bioenergetic adjustments, and that the (presumed) ancestral ability to cope physiologically with ambient heat stress has been lost by the amakihi (*L. virens*), which lives in high forests where ambient temperatures exceeding 35°C are seldom if ever encountered.

This paper is currently in preparation, to be entitled, "Energy metabolism, thermoregulation, and pulmocutaneous water loss in the Hawaiian honeycreepers, *Loxops parva* and *L. virens*", and to be submitted to Condor.

The objectives of this project are to determine the degree of genetic variation in speciating and non-speciating organisms. Initially, we are examining the highly speciated picture-winged Drosophila (Drs. Carson and Johnson and Mr. Steiner) and contrasting their variability with a non-speciating Drosophila, D. immigrans (Dr. Paik and Mr. Sung). Reports are attached.

We have also examined Metrosideros polymorpha, as an example of a successful non-speciating plant, and will eventually contrast this with a speciating plant such as Cyrtandra when suitable technical assistance becomes available. Mr. Steiner's report is attached. This project also relates to B-6, conducted by Miss Corn.

It is too early to speculate about the results obtained to date, but the non-speciating D. immigrans and M. polymorpha are clearly quite variable.

In order to correlate the activities of the Drosophila project with as many of the objectives of the IBP as possible we have placed strong emphasis on work along the Mauna Loa transect and in neighboring forests, such as the Kilauea Forest Reserve and the Olaa Forest tract in the National Park. Samples of Hawaiian Drosophila which were used for genetic analysis by cytological and electrophoretic methods have been obtained by collecting teams (14 people have participated). Baiting was done in a uniform manner in the same areas in April, June, September and December of 1971. In 218 man-hours of collecting during the first three trips 1082 specimens of the large (picture-winged) Drosophila were collected. The Olaa Forest is richer in species (13) than the Kilauea Forest (6 species) and the flies are more than twice as dense (7.8/man-hour vs 3.1/man-hour). We are planning to extend these collections to include three localities along the Mauna Loa strip road.

Eight of the 14 species found in the area display chromosomal polymorphism. Those species which do not have chromosomal polymorphism nevertheless display polymorphism for electrophoretic variants. Genetic analysis of population samples will be continued for another year in order to lay down a basis for the interpretation of 1) changes in adaptation in the event the environments are altered and 2) the relation of the genetic variability to speciation processes. Those working actively on this project are H.L. Carson and E. Craddock (cytology) and W.E. Johnson and W. Steiner (electrophoresis).

E-1
Yong K. Paik
Kee C. Sung

Progress Report on Genetical Studies on Speciation of Drosophila

(Analysis of Polymorphic State of Inversions in Hawaiian *Drosophila immigrans*)

Full statement of progress:

During the past 13 months we have initiated a long-term research project in an attempt to elucidate the evolutionary characteristics of *Drosophila immigrans*, a member of cosmopolitan species of genus Drosophila, in the Hawaiian Islands.

Before going into the details of the experimental procedures which have been followed and of the results which have been obtained, it would be appropriate to describe briefly the background of theoretical interest bearing on the current research project. As is well known, a great majority of Drosophila species are endemic to particular geographical areas of the earth. The majority of studies on the evolutionary aspect of Drosophila have been mainly confined to such endemic species, and the information of their evolutionary characteristics is now abundant and well organized. On the other hand, the majority of the cosmopolitan species have been put aside from study simply as "narrowly-adapted" species to some specific niches in or near human habitation. *Drosophila immigrans*, however, has been found to occur in a quasi-natural state on every continent, frequently remote from human habitation. This is, on the whole, an exceptional situation insofar as the habitat of the cosmopolitan species is concerned. Recently Carson (1965) pointed out a more interesting situation of the colonization of *Drosophila immigrans* in Hawaii where the species appears to be truly invading the natural state and even successfully colonizing endemic niches of mountainsides, competing there with the endemic Hawaiian Drosophila. This remarkable feature of this species in Hawaii has encouraged the present investigation, which is directed toward analyzing the underlying mechanisms of the superior adaptability of *D. immigrans* to a large number of different ecological niches in Hawaii. From a theoretical point of view, the success of this species in Hawaii, measured in terms of colonizing ability, can be explained in various ways. First, this might be achieved either by superior phenotypic adjustment if certain part(s) of the genome could serve to generate a kind of homeostatic ability to invade various ecological niches without genetic change. Secondly, it might be achieved by superior genetic adjustment through the formation of ecotypes (races) by selection and resultant local genetic change. The third possibility is that such a goal might be achieved through the process of transitions and/or combinations between the two previous types of adjustment. The related problems were fully discussed in a recent symposium by Carson (1965) and Dobzhansky (1965).

With these assumptions in mind, the first experiment was begun in late October, 1970 to test these hypotheses of the working mechanism(s) in the Hawaiian populations of Drosophila immigrans. The experiments were directed to assess to what extent the species is dependent on chromosomal inversions in its adjustment. Following this, parallel studies of morphological variation (visible mutation) were performed.

The population samples studied were taken by trapping on the islands of Oahu and Hawaii. The Oahu samples were from three different habitats: the first population sample was taken in late November, 1970, in Mt. Tantalus--moist forest--at 15-1700 foot levels. A second collection was taken in mid-January, 1971. These samples will be referred to as OT-70 and OT-71 respectively. Another sample was collected in Mt. Mauna Kapu--dry forest--at 2100-2300 foot levels in late October, 1970, and a second collection in early January, 1971. These samples are designated OM-70 and OM-71 respectively. The final sample was collected in mid-March, 1971, in Mt. Puu Keaau-cactus forest--at 100-1000 foot levels. This sample is designated OP-71.

The Hawaii samples were taken in early April, 1971, in Hawaii Volcanoes National Park (HS-71) and in Kilauea Forest Reserve (HK-71)--a virgin rain forest. In the first mountainside, samples were collected at six elevations along Mauna Loa Strip Road extending from 3000 to 6700 feet; in Kilauea Forest a single sample was collected at an altitude of approximately 5000 feet.

Data on chromosomal variations in the previous populations were obtained by studying the salivary gland chromosomes of two F_1 larvae in the progeny of each wild-caught female. Data on visible mutations are from 3 single pair-matings of F_1 progenies of each female caught in nature. The F_2 flies were carefully examined under the binocular microscope for mutant types. Total counts numbered at least 100 flies in most lines.

Before presenting the experimental data, it would be of interest to show one of our recent collecting records which clearly demonstrates the movement of Hawaiian D. immigrans in both the natural and endemic habitats. The following table summarizes the results of field collections on the island of Hawaii between April 7 and 11, 1971.

Drosophila species and their numbers collected at different altitudes in the vicinity of Hawaii Volcanoes National Park

	Collecting Sites							
	Moana Loa Strip Road					Kilauea Forest	Main Road	
Species	4000'	4300'	5100'	6100'	6700'	5000'	3000'	Total
D. engychoracea	5	4						9
D. mimica		29						29
D. imparisetae		18	2					20
D. pectinitarsus		1			3			4
D. basisetosa		1						1
D. silvestris						1		1
D. murphyi						1		1
D. fungiperda		1						1
Fungus feeder spp.	1	1						2
D. reducta	1		10					11
Antopocerus sp.							1	1
Scaptomyza cuspidata		10	46	7	8	2		73
S. (Tantalia) sp.		6						6
D. simulans*	73	45	127	1			38	284
D. busckii*			107	21				128
D. mercatorum*			1					1
D. immigrans*	301	138	164	13	22	11	36	685
D. kikkawai*							3	3
D. trichaetosa						2		2
D. sp (mitchell?)							1	1
Total	380	255	457	42	33	17	79	1263

*Denotes introduced species; the samples from 4000', 4300', 5100', 6100', 6700' at Mauna Loa strip road and from Kilauea Forest (point 1 of TR2) and Main Road will be referred to as HS-1, HS-2, H3-3, HS-4, HS-S, HK-200 and HS-300 in the context, in that order.

From the table one can easily see that D. immigrans is the most abundant and widely distributed among the introduced species within the area. Another interesting point of this collection is that D. busckii, known as domestic species, was also found in great numbers in the high elevations ranging from 5000 to 6000 feet.

Types and frequencies of the inversions found in the Oahu populations sampled at the three distinct habitats are given in the following table:

Frequencies (in per cent) of inversion heterozygotes in the Oahu populations (N, total number of larvae examined, one larva per line).

		Heterozygous Inversions						
Sample	N	A	B	C	A+B	A+C	B+C	TOTAL Het. Inversions
OT-70	83	25.3	2.4	1.2	--	--	--	28.9
OT-71	120	18.3	3.3	0.8	0.8	--	--	23.3
OM-70	53	24.5	1.9	--	1.9	1.9	--	30.2
OM-71	158	22.8	6.3	1.3	2.5	1.3	1.3	35.4
OP-71	54	18.5	5.6	--	3.7	1.9	--	29.6
All Samples	468	22.0	4.3	0.9	1.7	0.9	0.4	29.9

A, B, and C denote different inversions on the 2nd chromosome: A is located at about middle of the left arm, B at the subterminal part of the right, and C in the proximal part of the right.

The average frequency of the total heterozygous inversions in the Oahu populations was 29.9 per cent. Compilation of the total number of inversions of each type showed that the distribution of the inversions is uniform for the three populations ($0.25 > P > 0.10$). The mean frequency of heterozygosity per larva in the Oahu populations was 0.33, based on the total examinations of 903 larvae.

The results obtained for the Hawaii populations, however, do not appear to be in accord with the previous results as shown in the following table. First, the incidence of the inversion heterozygotes is generally higher at face value in the Hawaii populations as compared with the average frequency of the inversions in the Oahu populations. It is particularly noticeable to find the exceptionally high frequencies of the inversion heterozygotes in the HS-1 and HS-3 populations where the greatest number of samples were examined (see table). Secondly, it was also found for the two populations that the distribution of inversions is significantly nonuniform ($0.05 > P > 0.025$).

Frequencies (in per cent) of inversion heterozygotes in the Hawaii populations (N, total number of larvae examined, one larva per line)

		Heterozygous Inversions						
Sample	N	A	B	C	A+B	A+C	B+C	Total Het. Inversions
HS-1*	67	17.9	10.5	16.4	5.9	--	5.9	56.7
HS-2	12	25.0	--	8.3	--	--	--	33.3
HS-3*	101	31.7	9.9	6.9	5.9	2.9	2.9	60.4
HS-4	11	36.4	--	--	--	--	--	36.4
HS-5	15	26.7	--	6.7	6.7	--	--	40.0
HS-3000	24	12.5	--	8.3	4.2	--	4.2	29.2
HK-200#	10	10.0	10.0	10.0	--	10.0	--	40.0

* Statistical comparison for the distribution of the heterozygous inversions was possible only for these two samples (see text).

\# A new pericentric inversion of the 2nd chromosome was detected in the populations.

The significance test was made only on HS-1 and HS-3. It could not be made for all populations because sample size and the inversion incidence were too small for the other five populations.

In addition, the mean frequency of the inversion heterozygosity per larva in the HS-1 and HS-3 was found to be 0.66, based on the total examination of 334 larvae. This mean frequency is twice as high as that found in the samples from Oahu.

Thus, a comparison of the frequency and distribution pattern of the heterozygous inversions in the Hawaii populations from the HS-1 and HS-3 populations with those in the Oahu populations suggests that the three common inversions we have found there probably respond in different ways to the potential ecological differences between the two islands. While the precise reason for this difference cannot be ascertained at present, the data are apparently instructive and a more clear-cut explanation for this finding is expected from the results of frequency analysis of the different gene arrangements which is now in progress. However, the consistently lower frequency of the inversions and their uniform distribution throughout the three Oahu populations from the ecologically distinct habitats provided no indication of chromosomal adaptive changes in response to the different environments. Thus the Oahu data apparently suggest a successful colonization of D. immigrans in the different environments studied without essential genetic (chromosomal) changes. On the other hand, the explanation for the significant change observed in the distribution of the heterozygous inversions for the HS-1 and HS-3 populations in Hawaii Volcanoes National Park with the change of altitude (at 4000 and 5100 foot levels) is quote problematic at present. Whether this possible clinial change detected there is correlated with the ecological differences between the two altitudes is an open question, and more data are apparently needed. However, a clearer answer to this question is expected from the results of frequency analysis of the gene arrangements and the parallel results of the analysis of visible mutations which are now in progress. There is no evidence that the exceptionally high frequencies of the inversions and their non-uniform distributions in the HS-1 and HS-3 populations are the reflection of adaptive changes. Such a situation, however, may be viewed as an interesting challenge to further investigation. Consequently, work is being planned for elucidating the problem.

Another interesting finding in the present work is the detection of a pericentric inversion, which is relatively short and symmetric, on the second chromosome. It was found in association with the heterozygous inversion on the left arm of the second chromosome. It was detected only once in the examination of twenty smear preparations (2 smears per isofemale line) of the salivary glands of F_1 larvae of the 10 wild-caught females from the Kilauea Forest Reserve (virgin rain forest), Hawaii. From the review of the pertinent literature it seems to be the first case of pericentric inversion found in natural populations of D. immigrans. It is of great interest to clarify whether the same inversion persists in that natural population, since the incidence of pericentric inversion is known to be extremely rare, or none, in natural populations of many Drosophila species.

In addition, a series of experiments to determine the types, frequencies, and allelism of visible mutations is in progress. However, the work is confined to the Hawaii populations, and it is hoped that the results should provide some light to elucidate the previous problems regarding the genetic structure of these populations.

In view of all the information obtained from the present work, interpretation of the active colonization of D. immigrans on the Islands seems somewhat sophisticated. Obviously, the present results propose further investigation. The data obtained have pointed, at least in part, the way to opening up new avenues of attack on the underlying mechanisms.

A full account of the study will be published shortly. The research was supported by an Intramural Research Grant from the University Research Council and the University of Hawaii's International Biological Program Grant.

Technical Developments and Genetic Aspects of Variation in Metrosideros

E - 1

W. W. Steiner

Of current interest in the Island Ecosystems IRP/IBP Hawaii investigations is the question of why some species have undergone speciation while others have not. This student is currently involved in studying the problem from a genetic point of view using a biochemical genetic technique. Two groups of organisms are presently being investigated with respect to the above, the Hawaiian Drosophilidae (speciating) and the Metrosideros (nonspeciating). The subject of this report will deal with the latter group.

Metrosideros occurs in a wide range of environments and displays wide morphological variation. Of prime interest in relation to these factors are three questions of evolutionary interest:

1. How much of the phenotypic variation is a response of the plant to its environment and how much is genetic in nature?
2. Is the observed variation a product of subspecies formation?
3. What are the genetic factors or relationships which have provided the ability for Metrosideros to expand its range over such a diverse area yet enable the group to retain its unique status?

Electrophoretic analysis, a technique to separate enzymes which are direct gene products, is being employed to provide data useful in answering these questions. Table II lists the markers presently being developed and those which are currently in use. Other technical difficulties in developing these are presently being overcome, and the stain methods in Table II are being linked to the appropriate buffer system (Table I) for best results. For esterase, leucine aminopeptidase and phosphoglucomutase, the best buffer system is the tris-citrate gel (Buffer A, Table I) and the tris-citrate electrolyte (buffer F, Table I). This system is being further investigated to see if more stains (Table II) can be adapted to it.

Two other problems of relative importance have also been encountered. The first consists largely of concentration of protein in plant material. Plant cells are relatively large with heavy membranes, which in relation to animal tissues make up much less enzyme concentration per gram of material (which is harder to extract if the plant cell wall cannot be ruptured) than occurs in animal tissues.

The second problem involves naturally occurring plant phenols which, after homogenization of plant tissuem appear to disrupt electrophoretic banding patterns. This problem can be a serious one, since it apparently produces a molecular binding effect on the enzyme systems being analyzed for. This can hamper determination of genome heterozygosity and may effect genotype analysis as well. Phenolic compounds are well known to produce such effects (Scandalios, 1971; Babbel, 1971; McCown et al, 1968), however, to be certain that cell membranes were not involved, experiments were performed in which all extraneous cellular material was removed by centrifugation at 28,000 g. Electrophoresis of the supernatant showed enzyme activity still bound to the apparent carrier molecule.

That Metrosideros contains various phenols in the forms of flavenoids comes from evidence offered by Dr. G. H. Towers of the University of British Columbia. As of September 1, 1971, Dr. Towers has isolated and identified 6 such flavenoids, namely: Quercetin-3-arabinoside, Quercetin-3-galactoside, Quercetin-3-rhamnoside, myricetin-3-arabinoside, myricetin-3-galactoside and myricetin-3-rhamnoside. Evidence for the existence of an acylated galactoside also has been found.

Babbel (1971) has offered a technique for enzyme extraction (see materials and methods) which we are currently adapting to use. We have coupled this with the use of seedling materials in order to gain 3 advantages:

1. Standardisation of the plant material and use of the whole plant.
2. Reduction in the concentration of polyphenols which have not yet accumulated with age.
3. Higher concentrations of developmental enzymes and less rigid cell walls.

Though this requires that we be aware of developmental changes which may take place within the individual plant, standardisation largely resolves this problem. Furthermore, I am informed from Dr. Allard's lab at Davis (Babbel, 1971) that age-dependent variation cna exist even in adult leaves of the same plant. An experiment to investigate the extent of this pehnomena in Metrosideros was undertaken using leaf esterases. Leaves at various heights were collected on Oahu at 1600' elevation (Manoa cliffs trail) from the following adult Metrosideros growing within 30-50 feet of one another: typica (2 varieties), glaberima, glaberfolia and tremuloides. Differences in leaf esterase patterns were observed within the same plant, indicating the existence of age-dependent enzyme changes in adult leaves. This phenomena creates a major problem in standardisation for comparison between varieties. These reasons, then, influenced the decision to limit investigations concerning comparisons of varieties to comparisons between seedling plants of known age. The phenomena may also prove an insurmountable barrier to studying elevational and ecological relationships with respect to plant genotype and environmentally induced genetic changes. This area will be investigated further.

Investigations using seed types and pollen as experimental material have also been attempted. These have proven unfruitful. Seed types show no resolvable electrophoretic patterns. Pollen is too costly and time consuming to collect from field specimens, though Makinen et al. (1967) indicates it as a favorable material for isozyme investigation in readily attainable plant species. These areas of investigation have been abandoned. Since the discovery that age-dependent variation in adults applies to Metrosideros, and the development of the tris-citrate electrophoresis systems to enhance resolving power in technique, more recent findings may invalidate some of the previous findings. Though all evidence to date is considered preliminary, the most recent findings uphold the previous findings of apparently low levels of individual genetic polymorphisms and limited genetic variation between morphologically diverse types, (FigureI, Table III). Such variation, it is suggested, enables Metrosideros to meet environmental requirements over its range of distribution. Studies are presently being planned to further investigate:

A. the extent of variation between plants of the same type (i.e. typica) occurring at different elevations, by comparing protein patterns of seedlings from these.

B. increasing the extent of loci to be sampled to obtain better estimates of heterozygosity and genetic variation.

C. Developmental studies on seedlings to obtain an idea of similarity of enzyme changes between the same and differing types.

These studies may provide some clue as to the actual nature of the genotype-environment relationships occurring at the biochemical-genetic level. Figure II suggests that Roberts (1969) theory on isozyme substitution may indeed play a role in Metrosideros response (and thus ecotype selection). The within group variation (samples 3,4,5,8 and 9) shows that elevational differences may exist, and therefore these may play a role in meeting environmental vicissitudes. If this is the type of response we are observing, we should expect such variations to display seasonal changes within the individual at higher elevations as well. Though we cannot rule entirely the changes induced by age-dependent shifts discussed earlier, it is suggested that environmentally induced genetic responses would be an asset to an organism not having the ability to remove itself from the vicinity where stress conditions may exist. Favoring of high overall variation and low speciation tendencies might result because fracturing of the genome to produce species as a response to stress might remove favorable alleles required in adjustments from the overall population. As a result, outcrossing and hybridization would tend to be favored, and continual production of variability a method of meeting survival requirements. Such outcrossing appears to exist in Metrosideros (Corn, unpublished results), but further investigation as to the extent of hybridization could provide useful support. The concept may provide a basis for the lack of speciation observed in certain groups, and provides a base from which to further investigate the observed morphological variation in Metrosideros.

Materials and methods

Two types of gels are used in the analysis of plant material, and a variety of gel and electrolyte buffers are available (Table I). The gels are prepared in the following manner:

Acrylamide gels: 100 ml of the appropriate gel buffer is placed in a 500 ml erlenmeyer flask. To this is added 7 grams of cyanogum-41 (Fisher Scientific), which is dissolved with a stirring in the buffer. In quick succession is then added 5 ml of ammonium persulfate and .1 ml of N,N,N,N'-tetramethylethylenediamine (Eastman Chem. Co.). The solution is quickly stirred and immediately poured into a 0.02 cm x 18 cm x 21 cm lucite tray and covered with a glass plate to facilitate gel formation. After 1/2 hour the gel is ready for sample insertion.

Starch gels: To .175 ml of the appropriate gel buffer in a 1000 ml erlenmeyer flask is added 21 grams of electrostarch (Otto Hiller, Madison, Wisc.). The thick solution is stirred and cooked simultaneously over an open gas flame until boiling produces a thick, clear liquid. The liquid is immediately degassed for 1 minute, then poured into a .6 cm x 10 cm x 21 cm lucite tray and allowed to cool and set for one hour. The gel is then prepared for sample insertion.

The latter type of gel has been found to be most useful, since it can be sliced horizontally into three, 2 mm deep gel slices and each slice can be stained separately. This allows comparisons of different protein patterns of the same specimen with respect to mobility position on the gel slices, and reduces time spent in preparing gels to be used in analysis.

Sample preparation and insertion. Leaf, floral parts, or whole seedling have primarily been used for analysis. If adult tissues are used (i.e. leaf, stem, root, floral parts) care must be taken to maximize the weight of material used in relation to the volume of homogenizing buffer in which the material is ground up. For whole seedlings (14 days to 80 days) about .01 ml of distilled H_2O containing .03 M β-mercaptoethanol (Sigma Chem. Co.)/1000 ml and .1 grams of insoluble polyvinylpyrrilidone (PVP) per gram fresh weight of leaves or plant material is used as a homogenization/extraction buffer. The seedling is ground by hand with a mortar and pestle to produce a thick slurry, the PVP serving to complex out phenolic compounds which have a tendency to disturb electrophoretic patterns of migrating proteins. The β-mercaptoethanol serves to stabilize protein structure and prevent enzyme inactivation.

The supernatant of the prepared homogenate is then drawn off into a .7 cm x .6 cm (Whatman no. 3M) filter paper wick, which is then placed in the gel in a slice about 2.5 cm from one end of the gel. The gel is then covered with saran wrap to prevent excess drying, placed on the electrophoresis apparatus and attached to the anodal and cathodal chambers by sponge wicks.

Care should be taken in the homogenization technique to periodically examine the resulting slurry under a high-power microscope to determine if the technique is adequately breaking the cell membranes. This provides an effective control against the hand homogenization technique. The mortar and pestle should be kept on ice if possible. Electrophoresis is performed in a Perlick standing cold-box, kept at $4^{\circ}C$, with the length of the electrophoretic run depending on the buffer system used (Table I).

Stain techniques

After electrophoresis, the gel is removed, sliced and stained according to one of the techniques in T ble II. Leucine aminopeptidase (lap), esterase (est) and phosphoglucomutase (pgm) have only recently been developed to a workable stage, problems in micromolar quantities being overcome. The other stains work only sporadically and have not yet been standardized. From lap and est, some preliminary results may be reported.

Drs. G. C. Ashton and H. L. Carson provided laboratory facilities used in this study. Miss C. Corn provided plant material and identification.

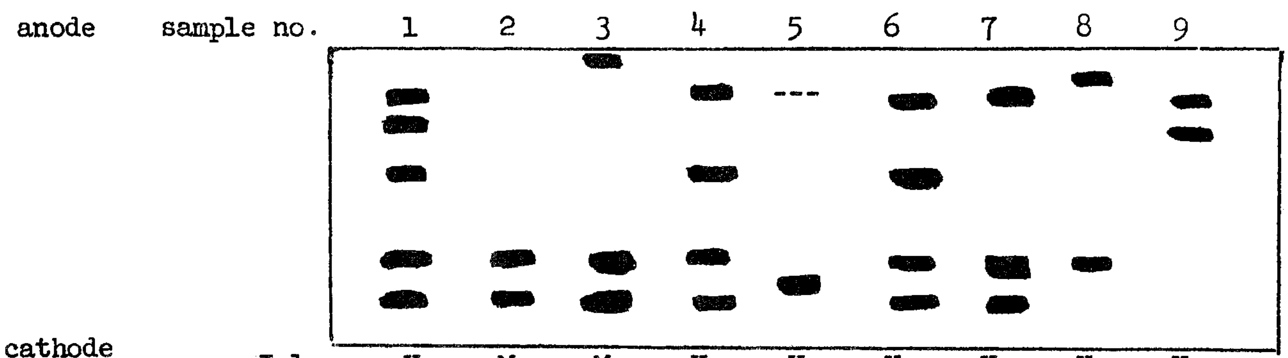
Publications in preparation

The following publications are presently being planned:

Steiner, W.; Corn, C. and Ashton, G. C. Developmental Genetics of seedling proteins in Metrosideros. I. The esterases, aminopeptidases and phosphatases.

Steiner, W.; Corn, C. and Ashton, G. C. Genetic variation and morphological divergence in Metrosideros.

Figure I. Examples of esterase gel showing variation in and between
Metrosideros types



Isle	H	M	M	H	H	H	H	H	H
Type	I	H	T	T	T	I	I-T?	T	T
Alt. in feet	750	6600	6600	750	6600	750	200	8300	7500

H-Hawaii M-Maui I-incana T-typica

Table I. Buffer systems currently under development and/or adaptation for the analysis of *Metrosideros* variation.

Code	Buffer	pH	To make	running voltage	running time	Enzyme	reference
A.	Tris-citrate (gel)	8.0	Tris--6.2g/L Citric Acid-1.2g/L				under development
B.	Tris-citrate (gel)	8.3	Tris--6.2g/L Citric Acid-1.6g/L				Scandalios, 1969
C.	Tris-glycine(gel)	8.7	Tris--3.0g/L Glycine--14.4g/L (dilute 1:9)				Scandalios, 1969
D.	Lithium-borate (elect.)	8.3	LioH--1.2g/L Boric Acid--11.9g/L	300	5 hours with buffer B	Est. Ap.	Scandalios, 1969
E.	Tris-glycine (elect.)	8.7	Tris---3.0g/L Glycine-14.4g/L (dilute 1:1)	300	18 hours with buffer C	LAP PGM	Scandalios, 1969
F.	Tris-citrate (elect.)	8.15	Tris--83.2g/L Citrate--33g/L (dilute 1:1)	200	6 hours with buffer A	LAP Est.	under development
G.	Phosphate C (stain)	4.3	NaH_2PO_4--27.8g/L				
H.	Phosphate D (stain)	9.2	Na_2HPO_4--56.63g/L				
I.	Tris-maleic A (stain)	3.3	Tris--24.2g/L maleic acid--23.2g/L				
J.	Tris-maleic B (stain)	14.0	NaOH--7.9g/L				
K.	Tris-Hcl (stain)	7.0	Tris--12g/L Hcl--to pH 7.0				
L.	Acetate buffer (stain)	4.0	acetic acid--410 ml Na acetate--90 ml H_2O-----500 ml				

Table II. Staining solution formulas currently being adapted for use in analysis of genetic variation in Metrosideros.

(Those marked with an asterisk are currently in use.)

Enzyme	Components	
*Esterase (est) pH 6.2	40.0 ml	distilled H_2O
	1.5 ml	α-napthylacetate (1% in 1:1 solution of acetone:H_2O)
	1.5 ml	β-napthylacetate (1% in 1:1 solution of acetone:H_2O)
	50.0 ml	Phosphate C (buffer G, Table I)
	10.0 ml	Phosphate D (buffer H, Table I)
	50.0 mg	Fast blue RR
*Leucine amino-peptdase (lap) pH 5.2	30.0 ml	distilled H_2O
	40.0 mg	L-leucyl-β-napthylamide Hcl
	40.0 mg	Black k salt
	50.0 ml	Tris-maleic A (buffer I, Table I)
	20.0 ml	Tris-maleic B (buffer J, Table I)
Malate dehydro-qenase (mdh) pH 7.0	50.0 ml	distilled H_2O
	50.0 ml	Tris-Hcl (buffer K, Table I)
	1.0 ml	DL-malic acid (.2 M)
	1.0 ml	NAD (.01 M)
	1.6 mg	PMS
	50.0 mg	NBT
Alcohol dehydro-qenase (adh) pH 7.0	50.0 ml	distilled H_2O
	50.0 ml	Tris-Hcl (buffer K, Table I)
	50.0 mg	Ethanol
	3.0 ml	NAD (.01 M)
	2.0 ml	PMS (.01 M)
	50.0 mg	NBT
Alkaline Phospha-tase (AP) pH 8.3	60 ml	Tris-citrate buffer (buffer B, Table I)
	60 mg	α-napthyl acid PO_4- Na salt
	50 mg	Fast blue RR
	10 drops	10% aqueous $mgCl_2$
	10 drops	10% aqueous $mnCl_2$
* Phosphoglucomutase (pgm) pH 7.0	60 ml	Tris-HCl (buffer K, Table I)
	10 units	G-6-pdh
	0.5 ml	$mgCl_2$
	2.0 ml	TPN
	0.1 g	glucose-1-phosphate
	2.0 ml	NBT (.5 g NBT/30 ml H_2O)
	3.0 mg	PMS
Catalase (cat)	100.0 ml	.5% H_2O_2
	100.0 ml	distilled H_2O
	100.0 ml	.5% KI solution with .5 ml HCl
	100.0 ml	.15 M NaOH

(to be applied in succession)

Table II. (con't.)

Enzyme		Components
Peroxidase (po)	1.0 g	benzidine in acetic acid, H_2O (9:36)
		mix 20 ml of above with 20 ml of 3% H_2O_2
general protein		buffalo blue black NBR in ethanol/H_2O/acetic acid (5:5:1)
Acid phosphatase (acph) pH 4.0	100 ml	acetate buffer, (buffer J, Table I)
	80 mg	α-napthyl acid phosphate
	80 mg	Fast blue RR
	1.0 ml	10% aqueous $mgCl_2$

Table III. Plant types surveyed for esterase, aminopeptidase and phosphoglucomutase variability. All runs were made on seedlings 49 days old. Sample B' is the control sample, and all allele designations are arbitrarily assigned with reference to it. Alleles designated less than 1.00 are more cathodal in migration (see C. Corn, Dept. of Botany, U.H., for key codings).

Key Sample	No. of seedlings assayed	es-1	es 2	es-2	lap-1	lap-2	Pgm-1	Pgm-Z
Newellis	10	1.00	.80	.70	1.00	.80	1.40	1.30
B'	10	--	.80	.70	1.00, .95	.80	1.40	1.30
K	6	1.00	.80	.70	1.00	.83	--	--
N	5	--	.80	.70	1.00	.83	--	--
A	2	--	--	.70	1.00	--	--	--
D	6	--	.80	.70	1.00	.80	1.40	1.30
1417	2	--	.80	.70	1.00	.83	1.40	1.30
J	1	--	.80	.70	1.00	--	--	--

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Technical Report on the Biochemical
Studies of Evolution in the Hawaiian
Drosophilidae

W. W. Steiner

This laboratory has, since May, 1971, begun an intensive electrophoretic analysis of the Hawaiian drosophilids. Particular attention has been focused on the 100 or so species comprising the "picture wing" group (Carson et al, 1970), since chromosomally and morphologically based phylogenies have been largely worked out for these organisms. The electrophoretic survey is intended to provide evidence which will be used to:

a) Support the chromosomally and morphologically based phylogenies and answer discrepancies between these (Kaneshiro, 1971).

b) Provide some indication of genic variation and heterozygosity between and within species, such variation providing the material upon which natural selection, leading toward species formation, can act.

c) Investigate the relationships between genic variation and individual genotype with respect to fitness, homeostasis and genetic flexibility under specified stress conditions (see Levins, 1963, 1965, 1968 for the mathematical concepts involved).

d) Investigate the contribution of genic heterozygosity to chromosomally monomorphic and chromosomally polymorphic species and possible modes of speciation utilized by these types (for background on this subject see Carson, 1959, 1968; Beardmore, 1960; and Ayala, 1971).

The problems currently being investigated above relate to the IRP/IPB goals involving speciation and evolution in endemic Hawaiian organisms. The first step in such a project is to identify the various enzyme loci to be used, the number and frequencies of natural alleles occurring at that locus, and the characterization of local populations with respect to these loci. We are presently at this level of development, and eventually hope to compare overall results against those obtained in the study of nonspeciating organisms (i.e., <u>Metrosideros</u>) currently under investigation also.

The following preliminary results concern allele occurrences between species. The data is subject to change as broader samples and more direct comparisons between species are made. Allele frequencies for some of the loci currently being investigated have been calculated but due to sample size have not been included. These appear in general to be suggestive of a lack of Hardy-Weinberg equilibrium in populations which are chromosomally polymorphic and which have recently undergone the serious drought conditions experienced in the field in the summer of 1971.

Further analysis in this area is dependent upon increasing loci samples and sample size and to check for effects of population subdivision which can affect Hardy-Weinberg calculations. Future research will follow the plans presented above.

DATA ANALYSIS

The loci reported upon in this paper include α-glycerophosphate dehydrogenase (α-gpdh), isocitrate dehydrogenase (idh), hexokinase - 1 (hk-1), hexokinase-3 (hk-3), esterase-2 (es-2), leucine aminopeptidase (lap), malic enzyme (me), malate dehydrogenase-1 (mdh-1), malate-dehydrogenase-2 (mdh-2), octanol dehydrogenase (odh), fumarase (fum), and alcohol dehydrogenase (adh). Allele designations are given where these have been worked out against set controls (Tables I - IV). In most cases, sample sizes prevent nothing more than identifying loci and species relationships. Increases in sample size will undoubtedly reveal more loci to be polymorphic than presently indicated (polymorphism at a locus interpreted as the occurrence of alleles other than the commonly occurring allele at a frequency greater than 5%). Low levels of individual polymorphism are indicated, however,by Rockwood (1971) in those species she investigated, which generally tends to support our data. The species marked with an asterisk have never been investigated electrophoretically. The data presented for idh, hk-1, hk-3, me, mdh-2, pgm, and fum likewise has not been previously investigated in the Hawaiian drosophilids. Thus all data in these areas are original findings and provide a base from which to expand further research.

Other loci anticipated to be useful include the alkaline phosphatases (ap) which preliminary investigation indicates as having 2-3 loci, acid phosphatase (acph), esterase-3 (es-3), glucose-6-phosphate dehydrogenase (g-6-pdh), 6-phosphogluconic acid (6-pga), xanthine dehydrogenase (xdh), succinate dehydrogenase (sdh), aldolase (ald), lactate dehydrogenase (ldh), and glutamate oxaloacetate transaminase (got). Some preliminary surveys indicate these as being potentially worthy of development, and indeed must eventually be included to reduce sampling error and provide better estimates of genic heterozygosity. A lack of funds at this time prevents such development and use, however.

The stains and buffer systems presently in use have been developed in this lab or adapted to use from several sources (see F.M. Johnson et al, 1966; Selander et al, 1971; Poulik, 1957). Later publications will carry the techniques used in analysis.

The following tables represent about 1/3 of the known picture-wing species. Though others have been investigated in this lab (to date, 46 species representing all the subgroups except Primaeva) these have not all been presented, the remaining data presently being unanalyzed. Some 100 species are presently known for this group.

A rough estimate of species relationships can be obtained from the Tables by comparing alleles with the same number designation or which have the symbol "c" (common allele shared between species) in those cases where allele designations have not yet been assigned. Only the most commonly occurring allele is designated at polymorphic loci. Undesignated polymorphic alleles may often be shared within subgroups. Likewise, some of the species alleles represented by "d" (different allele, not shared by those species having the common allele) may be common alleles in the within-group species in which they occur. Allele number designations are made by comparing allele migrations against a standard control (D. sproati) and against a subgroup control (see individual table descriptions for those species used as the subgroup controls).

The F_1 progeny from many of the species being investigated are also being analyzed to verify segregation relationships in polyallelic systems. Analysis of hybrids is also being conducted in attempts to establish linkage relationships for enzyme loci and verify homology of enzyme systems across different species.

Dr. W. E. Johnson kindly contributed some of the unpublished results included herein. Kenneth Kaneshiro provided species identifications in most cases. Dr. H. L. Carson provided lab facilities and much useful advice.

Publications in preparation

Several publications are presently in the planning stages but are necessarily dependent upon the completion of population surveys, species comparisons, and laboratory experiments.

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TABLE I. Hawaiiensis and Grimshawi Subgroups. All allele designations are tentative and are made using D. sproati as the standard and D. grimshawi and D. silvarentis as subgroup controls. Those loci indicated as polymorphic (P) may have alleles in common with other species in its respective subgroup. Polymorphic loci are being investigated for Hardy-Weinberg equilibrium.

HAWAIIENSIS SUBGROUP	sample size	α gpdh	idh	hk-1	hk-3	es-2	lap	me	mdh-1	mdh-2	odh	pgm	adh	Fum
D. gradata	2	--		--	--	.95	.60	--	--	.10		.25		
*D. hirtipalpus	1					1.00 (P)								
D. hawaiiensis	15	.85	c	c	d		.65	.98 (P)	.50	.10	.65	.35 (P)	c (P)	d
D. silvarentis	21	.85	d	c		.98 (P)		d	.50	.10		.30		
*D. gymnobasis	3	.85	d	d	d	.98	d	d	.50	.10		.35		
*D. heedi	23	.85	c	d (P)	d (P)		.65 (P)	d (P)	.50	.10		.35 (P)	c	c
D. recticilia	2	.85	c	c	d (P)		d (P)	d	.50			.35	d	c
GRIMSHAWI SUBGROUP														
D. balioptera	2						.58	--	.28	--				
D. crucigera	31	.90		.50	--	1.03 (P)	.58 (P)	1.00	.50	.05	.85			
D. grimshawi	10	.90		.40	.35 (P)	.98 (P)	.58	1.03	.50 (P)	.10	.98	.30	.30 (P)	.40
D. disjuncta	21	.85				1.00 (P)	.58 (P)	--	.61 (P)	.05 (P)	.85 (P)			

c = common allele, shared between species displaying it.

d = different allele. (see text)

A dashed line indicates enzyme displayed little or no activity in that species.

TABLE II. Orphnopeza and Pilimana Subgroups. All allele designations are tentative and are made using *D. sproati* as the standard and *D. grimshawi* as the subgroup control. See Table I for symbol references.

ORPHNOPEZA SUBGROUP	sample size	α gpdh	idh	hk-1	hk-3	es-2	lap	me	mdh-1	mdh-2	odh	pgm	adh	Fum
D. sproati	113	.85 (P)	.30	.50	.35 (P)	1.00 (P)	.65	1.00	.50	.05 (P)	.85 (P)	.30 (P)	.30	.40
D. murphyi	25	.85	.30	.40	--	.98 (P)	.60 (P)	1.00	.50	.05	1.00 (P)	.25 (P)	.30	
**D. reynoldsia*	1					1.08								
D. ochracea	1	.90				1.05								
D. limitata	3	.85 (P)				1.05 (P)	.63	--	.33 (P)	--				
**D. claytonae*	1	.80				--	.50	1.00	.50	.05				
D. villosipedes	1	.85						--	.50	--				
PILIMANA SUBGROUP														
D. pilimana	1					1.00 (P)								
D. lineosetae	4					.99	.58 (P)	--	.33 (P)	--				

TABLE III. Vesciseta, Paucipuncta and Adiastola Subgroups. All allele designations are tentative and are made using D. sproati as the standard and D. digressa, D. paucipuncta and D. adiastola as the respective subgroup controls. See Table I for symbol references.

VESCISETA SUBGROUP	sample size	α gpdh	idh	hk-1	hk-3	es-2	lap	me	mdh-1	mdh-2	odh	pgm	adh	fum
D. digressa	2	c	c	c	--			d	c	c		d	c	
D. virgulata	4	c	c	c	--			d	c	c		d	c	
PAUCIPUNCTA SUBGROUP														
D. basisetae	2	.87					.75	1.00	.90	.10	.50			
*D. paucipuncta	1	.87				.98 (P)		.98	.50	.10	.98	.30		
D. prolaticilia	3	.80				.98		--	1.05	.10	.98	.20		
ADIASTOLA SUBGROUP														
D. setosimentum	21	.85				--	.65 (P)	c	.90	c	.90	c		
D. adiastola	35	.85	c	c	d (P)	.98 (P)	.65	c	.90	c		c		
*D. clavisetae	16	.85	c	c	d		d		d	c		d		

TABLE IV. The Planitibia subgroup. All allele designations are tentative and are made using *D. sproati* as the standard and *D. silvestris* as the respective subgroup control. See Table I for symbol references.

PLANITIBIA SUBGROUP	sample size	α gpdh	idh	hk-1	hk-3	es-2	lap	me	mdh-1	mdh-2	odh	pgm	adh	fum
D. silvestris	(19)	.85	c	c	c	1.10 (p)	.55	1.00 (p)	.95 (p)	.10	.90	c (p)	.31 (p)	c
D. setosifrons	18	.85 (p)												
D. planitibia		.85	c	c	c	(p)	.55	1.00	.95	.10		c	c	c
D. cyrtoloma		.85		c				1.00	c	c		d (p)	d	
D. ingens	1						.65							
D. meopicta		.85		c			c	1.00	d	d		d	.31	
D. hemipeza		.85	c	c			c	1.00	d	d		d	c	
D. obscuripes		.85					c	1.00	c	c		d (p)	.31	
D. melanocephala		.85		d			d	1.00	c	c		d	d	
D. heteroneura		.85	c	d	c (p)		.55	1.00	.95	.10		c (p)	.31	c

G

P. C. Ekern

Progress report on meteorological studies.

Initially: Two climatic stations were installed:

1. August 1970: Kilauea forest at 5400' elevation in a forest opening in Koa, Ohia, tree fern complex.

   a. Hygrothermograph at 1.5 m in a standard shelter.
   b. Two rainfall gages in the open and nine beneath the tree canopy to estimate cloud interception.

   Weekly readings of the gages are coupled to chart replacement.

2. August 1970: Mauna Loa transect at 5350' elevation in a Koa complex.

   a. Hygrothermograph at 1.5 m in a standard shelter.
   b. Two rainfall gages in the open and nine beneath the tree canopy to estimate the cloud interception.
   c. A second thermograph, placed near the ground, was operated through July 1971.

   Weekly readings of the gages are coupled to chart replacement. The results of the first year of operation have been compiled.

Two additional climatic stations were installed, summer 1971.

1. August 1971: Mauna Loa transect, 6650' elevation at the end of the road.

   a. Hygrothermograph at 1.5 m in a standard shelter.
   b. Two rainfall gages in the open.

   Weekly readings of the gages are coupled with chart replacement.

2. August 1971: Kipuka Ki at 4200' elevation.

   a. Hygrothermograph at 1.5 m in a standard shelter.
   b. Two rainfall gages in the open.

   Weekly readings of the gages are coupled with chart replacement.

Recording raingages for 45 day operation were delayed in receipt, and failed from sundry causes after about 1 month operation, fall 1971. Radiosonde raw data from Hilo have been collected for detailed analysis of the inversion properties in the air mass upwind from the transects. The surface weather maps for the period are filed with the Meteorology Department, University of Hawaii, pending the establishment of the synoptic flow patterns during the study period. Instrumentation for solar radiation and net radiation (purchased on a Water Resources Research Center project) have been received and are under test prior to field installation.

I have been asked for my considered scientific opinion of the advisability of the proposed introduction of axis deer on the Island of Hawaii.

Scientifically, this introduction is indefensible. All previous experience shows that the inevitable result of the introduction of 4-footed animals on an oceanic island is degradation of the ecosystem, loss of vegetation and soil and of the animals which depend on these. The delicately balanced relationships between plants, animals, soil and water on an island evolved in the absence of terrestrial non-flying mammals.

It is common knowledge that as a natural ecosystem evolves, a complex system of compensations develops, and that any adverse influence induces a defense. In the absence of any particular such influence, no defense against it develops. The absence of mammals on oceanic islands has resulted in an ecosystem highly sensitive to trampling and browsing, with no capacity for recovery in the face of this treatment.

The Hawaiian Islands are famous, throughout the world, for their remarkable and varied biota. Because of ecological illiteracy and lack of appreciation by our forebears of this unique assemblage of plants and animals, many of them have been lost already. With every major alteration in the ecosystem, more will go. Some of this is inevitable, because of increasing population and the demand for space. But generally there is developing a deeper understanding of ecological relationships and of consequences, and with this, an appreciation of the value of preserving as much of the diversity of the natural world as possible. This has passed the stage where it is only esoteric knowledge restricted to a few ecologists. I have even listened to U.S. congressmen discussing these very values.

There is no longer any excuse for losing these things through ignorance. If we deprive our descendents of some of what makes the world, and especially Hawaii, an interesting place to live, it is now only because we don't care, not because we don't know.

Scientifically, I have no hesitation in saying that introducing deer on the island of Hawaii will, in the long run, be a catastrophe with no compensating benefit. If we want to be responsible for depriving posterity of part of what makes Hawaii the fascinating and scientifically important place it is, we may go ahead with this introduction. We have the island of Molokai as an example of what will happen. It is an example that has not been adequately studied, but the general lines of what has happened in the way of forest degradation are clear enough. If we want a repetition of this on Hawaii we could do no better than to introduce deer. It is clear that already we have lost more thany any thoughtful and appreciative person could countenance to the goats and sheep at high elevations. This is described in inimitable fashion by Richard Warner in his essay, "A forest dies on Mauna Kea" (Pacific Discovery 13(2): 6-14, 1960). Axis deer will take us much farther along the same path. Hawaii will lose just that much more of its uniqueness and fascination.

Of course, if immediate money returns are all that interest us, there may be room for argument. Certainly more ammunition and firearms will be sold if deer are introduced. Certainly a few guides will be employed and hotels will have something to advertise that the hunters can understand. More hunting licenses will be sold. There will be short-term economic gain.

It will doubtless be some time before the general cultural level will be raised to the point where large numbers of people will want to come as tourists to see such things as tree lobelias, fern forests, and plant successions on lava flows. But it is most likely that, as leisure time becomes more plentiful, such interests will spread and become more general. Then it would be a great pity, even economically, if all the unique biological features had been sacrificed to the interests of a few hunters.

It has been claimed that the axis deer pose no threat to the wet forests of Hawaii. This claim does not seem valid to casual observation, but there has been no systematic and impartial investigation of such facts as are available. It would seem essential, before bringing deer to Hawaii, that such an investigation be carried out. The claim that placing the deer in an enclosure on Hawaii is for purposes of investigation is not even worthy of a respectful hearing. Anyone who has watched these animals in the field knows that a sheep fence will not contain them.

Conservationists will not be satisfied with any investigation carried out by the State Fish and Game Division, or any other government agency, as these are all subject to political pressure and most officials in such agencies consider that they are paid by the hunters and their objectivity is immediately suspect. It has been suggested that an independent scientific agency, such as the New York Zoological Society, or the Smithsonian Institution, perhaps backed by a foundation grant, or by State money with no strings attached, should be commissioned to carry out a thorough investigation of this question, to determine, once and for all, what the effects of axis deer at various population levels have on the native flora and vegetation, and indirectly on the animal life that is dependent on the plants.

What is really up for decision is the level of civilization that the people of Hawaii have reached. If money and short-term advantages outweigh the long-term quality of the environment they bequeath to their descendents, their cultural level must be rated as low, indeed.

F. R. Fosberg

The Feral Goat in Hawaii, with Particular Reference to Problems in the National Parks.

Position Paper No. 2

The goat has been present in the Hawaiian Islands for nearly 200 years. In the feral state it is a hardy and prolific species that is regarded by many sportsmen as a game animal. On the other hand, the goat is an inharmonious element in native ecosystems and has caused extensive damage, modifications and also probable extinctions relative to the indigenous flora and fauna. Feral goats will continue to occupy large areas of wild lands in Hawaii and thereby will provide an elusive challenge to the capacities of professional game managers.

The goat presents a serious but needless threat to the integrity of many natural areas in Hawaii, including the National Parks. These parks were set aside on the same basis as other National Parks across the country, for the full protection and wise management of unique esthetic and scientifically valuable examples of natural phenomena, for the enjoyment, instruction and edification of all the peoples of the Nation. Introduced herbivores, such as the goat, are not natural elements in these settings and do not rightfully occupy a niche in them.

The HAWAII CHAPTER OF THE WILDLIFE SOCIETY is deeply concerned about the continued presence of intolerably large populations of feral goats in the National Parks of Hawaii, especially in Hawaii Volcanoes National Park. A recent decision by the Park Service to institute a "management" program as a concession to local hunting interests will, in effect, perpetuate high populations of goats in vast areas of the Park. Coupled with this decision is an apparent reversal of a previous commendable policy directed toward an eventual elimination of goats from Park lands. This disturbing action will also largely negate a program for re-establishment of native trees and other plants where they have been extirpated by goats.

The argument has been advanced that goats are needed to control exotic grasses. This argument is without merit. It has been shown adequately that goats do selectively or completely suppress native vegetation of the Parks, regardless of their effects on introduced plants, and maintenance of goats cannot be condoned for control of exotics.

Small demonstration exclosures have revealed after only two years that goat-free areas can stage a remarkable recovery of certain indigenous vegetation types. Although exotic species may not disappear from all goat-free sites in our time, the vitality and aggressiveness of native plants is probably underestimated in situations of free competition with exotics. Predictably, removal of goats will establish a long-term self-healing process in the vegetation.

It shall be the position of the HAWAII CHAPTER OF THE WILDLIFE SOCIETY:

1. To encourage the National Park Service to adopt and enforce a policy for the eradication of feral goats from all areas of the National Parks in Hawaii.

2. To encourage that methods used include: (a) immediate and repeated drives of goats; (b) fencing of critical boundaries and internal manage-

ment units to create barriers to free movement of goats into and within the Parks; (c) utilization of deputized hunters under supervision of Park personnel to reduce numbers of goats throughout the Parks as this program is developed.

3. That a high priority be given to the goat eradication effort so that reasonable and continuous progress will be made.

4. That the project for re-establishment of native vegetation in the Parks be renewed and kept in step with permanent removal of goats.

5. That persistent attention be given to scientific study of the biology, behavior, ecology and control of the feral goat in Hawaii, as a game species and as it pertains to native ecosystems.

6. That management of goats on lands not controlled by government agencies be intensified, specifically by encouraging agreements to permit public hunting on privately operated lands, particularly on Hawaii Island, Molokai and the southern slope of Haleakala on Maui. This action should provide an adequate control of these populations and assure sustained hunting opportunities for the public where feasible and desirable.

7. That introduction of goats to regions of Hawaii not now populated by them be discouraged.

8. That goats be eliminated completely from Kahoolawe and Lanai islands--from Lanai because the remnants of native forest are much too valuable as watershed and for scientific purposes to allow their further and perhaps final destruction, and from Kahoolawe because on that island, goats serve no useful purpose and will continue to cause deterioration of the vegetation and soils.

It has been stated in reference to the Mediterranean Basin, that the goat-herding stage is the final stage of civilization. Let us, in Hawaii, cease following this route to oblivion.

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This POSITION STATEMENT has been adopted by the HAWAII CHAPTER in furtherance of the objectives of THE WILDLIFE SOCIETY:

1. To develop and promote sound stewardship of wildlife resources and of the environments upon which wildlife and man depend.

2. To undertake an active role in preventing man-induced environmental degradation.

3. To increase awareness and appreciation of wildlife values.

4. To seek the highest standards in all activities of the wildlife profession.

P. Q. Tomich for HAWAII CHAPTER, THE WILDLIFE SOCIETY
December 10, 1971

Synopsis of the Views of Dr. F. R. Fosberg
Relative to the Harvesting of Koa and Hapuu
on the Big Island

Position Paper No. 3

These views were presented in a forty-five minute interview with Mr. Richard Lyman (Trustee, Bishop Estate). Dr. Fosberg consumed most of the time. A tape recording of the interview is available.

The koa proposal needs to take but little of our time as, indeed, it took little of Dr. Fosberg's. He feels that proposals developed by Mr. Norman Carlson (Bishop Estate Forester) are eminently sensible, and with competent help in carrying out should be sound.

The hapuu (Hawaiian tree fern) presents a different and much more complicated problem. The following factors were advanced by Dr. Fosberg:

1. The hapuu is not a decadent forest, but is probably stable at the pre or post climax level.

2. There is no doubt that there is a big market for hapuu.

3. Hawaiian hapuu has certain unusual characteristics which make it of particular value. Other varieties which do grow faster do not have these qualities and therefore should not be introduced.

4. Remarkably little is known about hapuu. Whether it can be artificially propagated to establish a sustained yield needs careful study.

5. Should substantial quantities of hapuu be removed, it is likely that some exotics would take over. This problem of the exotics appeared to be of great concern to Dr. Fosberg who feels the need for a control program to be urgent.

6. Certainly it would be an error of the first magnitude to bulldoze the 3,000 acres and harvest all of the hapuu. This probably would be an uncorrectable error, for we do not know what we would get back, but the chances are it would not be hapuu.

7. The man who has been given permission to harvest eleven acres has done a poor job, having apparently become a little bulldozer-happy. But since this has been done, a study of sustained length should be undertaken to determine what happens as a result.

8. On land not now in hapuu, experiments with its artificial propagation should be undertaken.

9. As to the specific proposal that 200 acres be harvested with care and the results studied, Dr. Fosberg appeared unwilling to say whether it was a good idea or not. This failure to take a position seemed to stem from his feeling that just not enough was known about the problem. In such a situation, scientists become conservative.

If the decision were made to go ahead, he would be willing to make an on-site study, time permitting, to develop guidelines.

September 16, 1971

Position Paper No. 4

I. A PROGRAM FOR ESTABLISHING NATURAL AREA RESERVES IN THE HAWAIIAN ISLANDS

1. Definition. A Natural Area is an ecosystem in which the modifying influences of technological man are kept to a minimum. A native forest may be a good example of a natural area, but the definition is not restricted to undisturbed native vegetation. Natural and undisturbed are often considered equivalent concepts. To avoid this misconception, I suggest that we designate a natural area as an ecological reserve. This term draws attention to a system in which usually many biota interact with one another. Disturbances (= perturbations of a non-technological nature) are part of such living systems.

2. We may recognize two kinds of natural ecosystems or ecological reserves:

   (a) Representative

   (b) Unique

   A representative ecosystem is a type-sample of a recurring ecosystem that can be found over a relatively large geographic area or repeatedly in different geographic areas in the same macroclimate. An example is the ohia-tree fern forest. Representative ecosystems should have an approximate minimum size of not less than 1000 acres. However, depending on local conditions, we may accept as representative certain areas as small as 200 acres (800 x 1000 m). Since representative areas are samples of something larger, they should also have a maximum size limit. I suggest a maximum size limit of 10,000 acres. It is important that the acreage available for ecological reserves is not swallowed up by only a few representative samples. Instead, we need to establish samples of all important Hawaiian ecosystems.

   A unique ecosystem is one that has very important individual characteristics. The small silversword population near Wailuku Gulch on the east-flank of Mauna Kea is an example, or the sandalwood forest on the west-side of Mauna Loa. These unique ecosystems are generally smaller and they may be one acre or less in size. They are usually already remnant examples, and their establishment as reserves must receive special attention and urgency.

However, establishment of unique ecological reserves, which will require more documentation, should not hold up the progress in establishing a system of representative ecological reserves on each of the 6 larger Hawaiian Islands.

3. The 1971 Report of the State Dept. of Land and Natural Resources for 1969-70 lists on p. 49 Table 8 Forest Reserves by Islands.

On this basis we may establish arbitrarily a certain acreage (20%) and number of representative Ecological Reserves (= Natural Areas).

Island	Acres in Forest Reserves (in thousands) All agencies	State owned	Acres in Ecological Reserves (in thousands) State owned
Kauai	163	83	17
Oahu	123	30	6
Molokai	46	20	4
Lanai	6	0	0*
Maui	159	86	17
Hawaii	699	581	117
			162

4. If we assume that a larger number of ecological reserves would have a mean acreage of about 1500 acres, we can set a target of 100 Ecological Reserves by 1975. It would be appropriate for the State of Hawaii to lead the U.S. in a program of establishing Ecological Reserves. This

* We should find a way to get at least one 1000 acre reserve on Lanai.

would be appropriate, because Hawaii is the only state that lies in the confines of the tropics, and it is the state that has the most to offer in natural beauty and uniqueness of biological resources.

5. Layout of Ecological Reserves. They should be laid out in altitudinal belt-transects that cut through a maximum of variation in vegetation, habitats and climates. Ideally, these belt-transects should be continuous from mountain tops to sea level. But by necessity, they may have to be arranged in an interspersed plot series, each plot about 1000 acres of minimum size.

6. The objective should be to go ahead as quickly as possible with setting aside the representative Ecological Reserves in State owned Forest Reserves and other more readily accessible ownership categories. We may even reduce the target date, or increase the number of representative Ecological Reserves. But 25-30 Ecological Reserves established per year until 1975 would set a good record that would boost the State's image considerably on the national and international level. At the same time, we should process areas that are unique and that need immediate protection because they are endangered.

II. POINTS ON HAWAII TIMBER PRODUCTION

1. Letter of Hiram Fong to Steve Montgomery (dated June 4, 1971) says: "I believe that intensive production of Southern Pine and possibly other species of trees would be a distinct economic advantage to Hawaii's housebuilding industry."

2. Question: What are the lumber needs of Hawaii's housebuilding industry?

3. A paper by G. D. Pickford (Hawaii State Division of Forestry, entitled HAWAII FOREST FUTURES, 1 page, undated, probably 1963) says: "Hawaii uses more than 100 million board feet of timber products annually."

But: "only a million board feet of lumber are produced in the State."

4. Questions: Is it worth it to help Hawaii's housebuilding industry by providing (presumably) cheaper wood for construction purposes? Who is the beneficiary?

5. If the benefits are to be passed on to the consumer (following the slogan "The most good for the most people"), a cheaper price for family housing requires raising the local lumber production from the 1% in Pickford's estimate to at least 20% per year. (This is a conservative estimate.)

6. In that case, a large acreage of Hawaii forestland would have to be planted to commercial timber species.

7. What forestland would be available for such an increased timber production?

8. Letter of Hiram Fong of June 4, 1971 says:
"A recent inventory has shown that there are a million acres capable of growing renewable tree crops."

9. This figure appeared in the 1963 report by R. E. Nelson & P. R. Wheeler "Forest Resources of Hawaii -- 1961," according to which 27% of the State's total land were classified as commercial forestland.

10. Note that almost 40% of these (a little over) one million commercial forestland is covered by non-commercial forest, mostly native ohia forest.

11. Therefore, implementation of a timber production program to benefit the consumer financially would require further substantial conversion of native ohia forests (primarily on the Big Island) to timber production forests.

12. What would we gain? A faster growing commercial tree crop perhaps. But a doubtful economic benefit: In our rapidly changing times, many

wood-substitutes have come on the construction market. Timber from standard timber-growing areas, such as the Pacific Northwest may be as cheap or expensive as locally grown timber. (Think only of the price of banana or pineapple in mainland supermarkets as compared to island stores.) Housing development in the state will undoubtedly be away from single-family housing to multi-family housing. Such larger city structures are not made from wood anymore.

13. What would we lose?

(a) The last larger reserve of truly virgin forest in the United States. A native forest vegetation that has never been exploited for timber before.

(b) A forest vegetation that is unique on the entire surface of our planet.

(c) The only tropical forest in the limits of the United States.

(d) The greatest resource of knowledge for the study of biological evolution.

(e) A resource for education and recreation enjoyment in the appreciation of biological diversity.

14. These losses cannot easily be measured in money values, because they are cultural values.

III. HAWAII FORESTRY OBJECTIVES TO BE ENCOURAGED

1. Forestry is an important professional field because Forestry is concerned with the proper caretaking of all non-agricultural land resources outside the centers of urban development and human habitation. In the State of Hawaii this relates to about 50% of the land area or about 2 million acres.

2. It is the proper caretaking of these lands, vegetation and water resources

that makes Forestry a profession. It is not merely the skill of exploiting these resources for financial gains, public or private.

3. In view of the state's unique biological values summarized under point 13 in the statement about "Points on Hawaii Timber Production," it is suggested to ban all exotic tree planting as replacement of native forest vegetation.

4. A number of Forestry Objectives are to be encouraged in the State of Hawaii. These are:

--to encourage reforestation of poor-quality exotic replacement vegetation that became established through fire, grazing and abandoned cultivation particularly in the lowlands;

--to encourage koa and tree fern silviculture on a limited scale. This should firstly be carried out on poor (low-production) grazing land that has been under koa before conversion;

--to encourage watershed research and watershed management. As recognized in the earlier Hawaii State Forest Policy up to 1960, water as correlated with forest vegetation, and function of the forest as a protective cover and water flow regulator should again become one of the primary concerns. Water needs are constantly increasing;

--to encourage research into the effects of introduced mammals on Hawaii's vegetation and ecosystems;

--to encourage "pest" control, for example of banana poka and other obnoxious foreign plant invadors in the sense of liberating regenerating native tree individuals from being overgrown by competition. In contrast, whole-scale eradication programs should not be encouraged, unless they are well-proven biological controls.

D. Mueller-Dombois for
Hawaii State Commission on
Natural Areas
December 10, 1971

ISLAND ECOSYSTEM STABILITY AND EVOLUTION

This subprogram is concerned with the study of terrestrial ecosystems that evolved in complete isolation in the midst of the Pacific Ocean (Hawaiian Islands).

The uniqueness of this isolation is the presence of the same principal environmental components as in many tropical mainland ecosystems, but with the point of departure that the biotic component was extremely restricted in origin. This original biotic component has evolved into a diversity of its own.

The main problem in the island ecosystems is that to the endemic diversity has been added a non-evolutionary diversity through man-introduced biota. A competitive struggle is going on in many ecosystems that threatens to wipe out the endemic diversity in several of the island habitats. However, man has been the principal direct factor in lowering the resistance of the endemic island ecosystems.

This subprogram aims at uncovering the fundamental causes in this competitive struggle to gain insights into the stability-fragility relations of those native ecosystems where the direct interference of man was held at a minimum. This requires observations also in man-disturbed ecosystems for experimental comparisons.

Strategy and objectives

These are directed toward

- Intensive studies of a few selected ecosystems whose species composition and structure has been the result of island evolution.

  The main questions asked are:

  1. What is the nature of their compositional and structural variation?
  2. What are their directions of development?
  3. What are their rates of population change or maintenance?

- Comparisons of ecosystems along well defined environmental gradients (transects) to study the factors and mechanisms responsible for changes in ecosystem stability.

  The main questions asked are:

  1. What is the effect of physical environmental change on stability along the transects?
  2. Of what nature are the interrelations of diversity and stability along the transects?
  3. What is the relationship between life form composition and distribution (structure), regulatory organisms (dominants) and stability along the transects?

- Comparisons of successful endemic populations regarding their mechanisms of adaptation to the island ecosystems.

  The main questions asked are:

  1. Why do some of the successful biota show incomplete speciation, while other successful ones show fragmentation into many species?

  2. What factors determine their relative success?

  3. What are the rates of speciation?

- Eventual comparison of the stability of island ecosystems to environmentally and structurally similar continental ecosystems.

Current activities

A. Intensive study of selected ecosystems

A comprehensive ecological survey was begun in a 200 acre site occupied by a native montane forest ecosystem. The principal structural components are scattered, tall, big-diameter Acacia koa trees and groups of Metrosideros polymorpha with several other native tree species as subcanopy members. A third major biomass stratum is formed by tree ferns (Cibotium spp.).

The base lines were surveyed and two 1000 m long transects were flagged out with 10 plot points at intervals of 200 m. The first sample plot has been completed. In addition to the plant ecological survey, insect and bird surveys are carried out along the same transects. Malaise traps and attractant logs have been placed at various strategic positions in this forest.

A climatic station was installed in August at this site for continuous recording of temperature and humidity. Rainfall in the open and under trees is checked at weekly intervals. Precipitation measurements under the canopy are particularly important here, because of the suspected high moisture contribution from cloud interception.

Check lists of all biota in this forest are currently prepared, and further sampling techniques are being worked out. Nine investigators are contributing to this study.

B. Ecosystem transect study

Six ecosystem transects have been defined and described on Hawaii. These range from 10-22 miles in length. One of these extends from the top of Mauna Kea (near 14,000 feet elevation) to the sugar cane fields above Hilo. Another lies parallel to the Mauna Kea transect on the east flank of Mauna Loa, where it traverses similar climates but much younger substrates. The four remaining transects are in Hawaii Volcanoes National Park and extend the Mauna Loa transect down to sea level.

Most the the 30 principal ecosystems along these transects have been studied by about two 500 m^2 vegetation samples each. The plot locations are currently transferred on a new 1 : 24,000 vegetation map, which is prepared under this subproject. Field work for the map is completed. Sixty-two plant check lists with quantitative information on species cover are currently programmed for computer storage, retrieval and various summaries to be available for any project participant. The same will thereafter be done with the insects and other biota checklists that are coming forth in the near future. Nine investigators have so far contributed to the transect study principally by attempting to establish the diversity of their particular biota in the various ecosystems and by defining the amplitudes of species along the transects. Seven phenological and two climatic stations were established in different macroclimates along the transects.

c. Evolution studies on endemic populations

Most of this work has been done along the transects, but some highly specialized populations, such as the Hawaiian Diptera and certain Hawaiian birds have been followed into different areas. The same is true for the genecological studies of the widely distributed polymorphic tree Metrosideros. The evolutionary objectives are pursued on all major islands, particularly on Hawaii, Maui and Kauai. They are not necessarily tied to the transects.

The ecological studies will be extended eventually also to Maui and Kauai.

Submitted for inclusion
in the Progress Report of the
ORIGIN AND STRUCTURE OF ECOSYSTEMS main project
by
Dieter Mueller-Dombois
Scientific Coordinator
Hawaii IBP

February 22, 1971

March 4, 1971

CIRCULAR LETTER TO HAWAII IBP PARTICIPANTS

By Dieter Mueller-Dombois, Scientific Coordinator

This is a follow-up message to our workshop meeting of March 2, 1971.

Among the several items discussed at that meeting I emphasized the need for an improved ecosystem model for our transect study.

HAWAII ECOSYSTEM MODEL

Starting from our first descriptive model FIGURE 15 in our funded February Proposal, I put on the board what I considered a somewhat improved model. This is here attached as fig. 1.

The model shows the 4 main components - climate, position, vegetation and soil or substrate - by which each ecosystem along the transects is defined. In the center appears the dominant organism responsible for the general structure of the ecosystem. This organism or combination of dominant structure-forming organisms also provides for a secondary environment (or stand climate) that is regulating to a greater or lesser degree the life functions of the associated biota.

The latter are shown as radiating out from the center. Names of principal investigators are attached for further information on how our program is integrated.

In terms of functions we can summarize:

1. The primary producers (higher plants, dominants and undergrowth, mosses, lichens, algae).

2. The consumers (mammals, birds, snails, fungi, phytophagous insects, sap-sucking insects, fruit and seed feeding insects, bark and wood feeders).

3. The decomposers (soil arthropods, mites, fungi, litter ants and inquilinous coleopterous scavengers).

4. The parasites and disease-causing organisms (we have so far 3 groups considered only: vertebrates, endemic insects, Drosophilidae).

5. The pollinators (we have no one specifically working on this important aspect of ecosystem function. Hirashima from Japan was elected to work specifically on insect pollinators, but he will enter the study only in the 3rd year; the role of birds should be particularly considered here).

We may identify other important ecosystem functions of specific biota as we gain more knowledge of our selected ecosystems.

ECOSYSTEM STABILITY

I would like to remind you that our key research inquiry is ECOSYSTEM STABILITY.

How do we incorporate this problem into our program for the purpose of getting an integrated result soon?

I see a possibility for an integrated study of the eight ecosystems, shown as segments 2 through 9 on the attached fig. 2. This is the now reasonably familiar east-flank ecosystem profile on Mauna Loa. Segment 9 stands for Kipuka Ki and Kipuka Puaulu, a well developed forest ecosystem type.

I expect that we find only in these kipukas (and also in the Kilauea koa-ohia-tree fern forest, for example) the full complement of biota and interactions as visualized on fig. 1. As we move upward the Mauna Loa slope from here, rainfall and temperature both decrease simultaneously. This macro-environmental change upslope is clearly reflected by significant changes in the dominant structure-forming organisms. The latter changes gave rise to the recognition of the eight different ecosystems that follow upslope from Kipuka Ki.

Associated with these structural changes we can surely expect for each of the other biotic components the following;

1. Changes in abundance (population size).

2. Changes in number of species in each biota group.

3. Changes in adaptation (to the extent of speciation).

4. Changes in the composition of native and exotic organisms in each biota group.

The magnitude in modification of the stand environment (central position, ecosystem model) is expected to decrease with size and spacing (or density) of the dominant life forms from a macro-environment which is strongly modified by the stand environment (in the kipuka forests) to an almost direct effect of macro-environment along the ecosystem gradient:

forest ⟶ scrub ⟶ herbaceous cover ⟶ moss and lichen cover.

This sort of ecosystem gradient, however, somewhat more complicated, exists upslope from Kipuka Ki (4000 feet) to Puu Ulaula (Red Hill at 10,000 feet).

By relating the above biota changes across this transect portion to one another we can produce the first basic integrated results of our program in a reasonable time, let's say by December 1972 (in time for the Second Progress Report). This would ensure our funding through the anticipated 5-year period.

INTEGRATION IN THE FIELD

I suggest that we begin by proper integration in the field as follows:

Fig. 2 shows under the segment numbers (2-9) 21 relevé or plot numbers relating to already once studied field-areas that were considered representative for each of the ecosystems. The plots are all mapped on the attached 4 map sheets. These are reductions of half sheets of the standard 1 : 24,000 topographic map sheets for the transect section of fig. 2. These reductions are at a scale of 1 : 48,000 (i.e. 1 cm on the map = 480 m in the field). The Kilauea sheet is here added for convenience.

It would be good for those of you interested in this integrated transect study if you would use the same study locations. The plant check list transfer for the 21 relevés (but also for the others) to the computer will be completed soon. We also have quantitative data, soils, rainfall and temperature data. The latter from extrapolation of the nearest climatic stations. What is needed, is the analysis of your particular biota in the same areas along this transect.

As soon as you produce your species lists, we should transfer them to the computer. The same will apply to any of the quantitative parameters. I believe it will be useful to first establish the patterns, then to correlate them and then to work on explanations.

I will mark in the field the 11 plots in transect segments 7-9 in April, so that you will be able to find the locations. The 10 plots in segments 2-6 are along the trail above the Mauna Loa Rain Shelter. The trail starts from the end of the road. You can locate these plots yourself with the help of an altimeter. However, if anyone wishes me to mark these also, I will do so.

NEED FOR FURTHER THOUGHT-INPUT

Obviously the model on fig. 1 is crude. We need to work on its refinement. I would like herewith to suggest to everyone on the program who works with a particular group of biota to compose an interaction model for his own group. In this case, you put your organisms in the center of a diagram and start building the ecosystem components around that you find are interacting with your organisms. Then identify the nature of these interactions. Do these for the kipuka forests and then through the other seven ecosystems upslope to segment 2 (fig. 2).

We will have another workshop meeting in early May. At that time it would be fine if you could present on one sheet a pictorial or box model (similar to fig. 1) for your particular organism at least for one ecosystem type, let's say a forest ecosystem. Please make 30 copies of your diagram for distribution to the other program members.

This will greatly help in identifying the areas of interaction among our group and will significantly help in the needed interpretation of population patterns that we will identify along the Mauna Loa transect.

FIGURE 1. ECOSYSTEM MODEL FOR TRANSECT STUDY (an approach towards a second approximation)

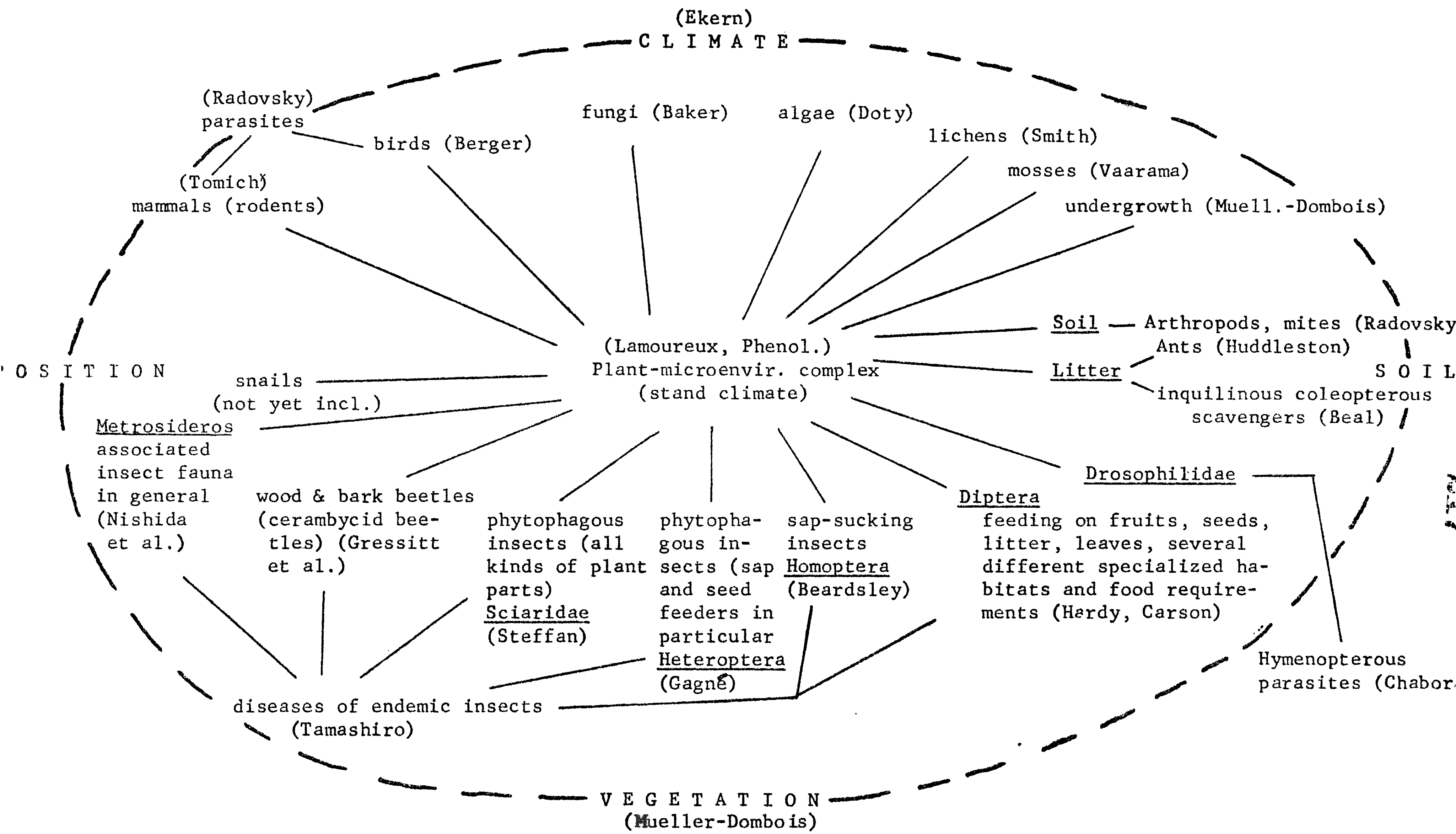
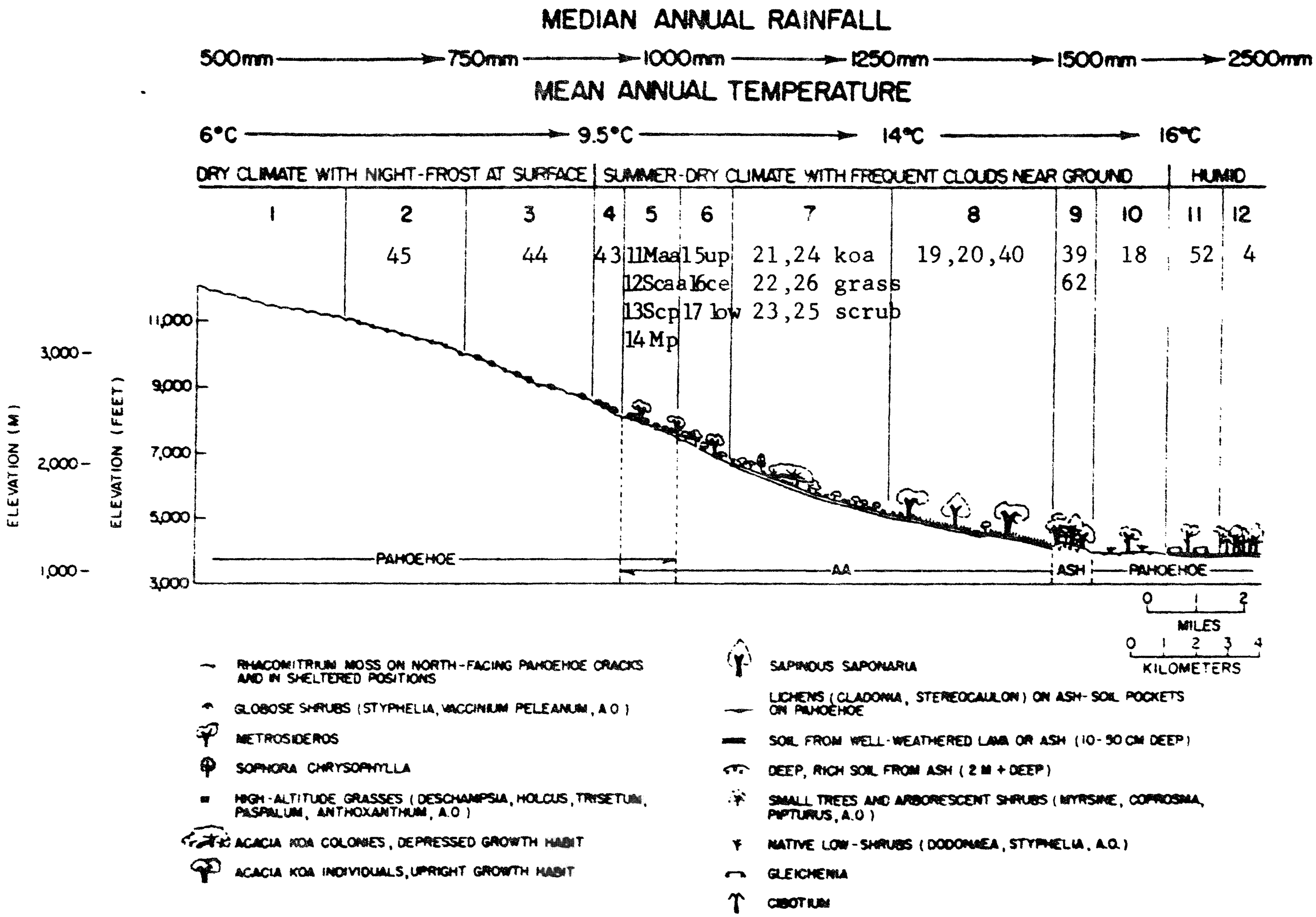


FIGURE 2. Mauna Loa east-flank ecosystem profile with plot locations (Transect 1 on Fig. 12 in Technical Report #1, IBP).



1. Vegetationless stone desert. 2. *Rhacomitrium* moss desert. 3. *Vaccinium--Styphelia* low-scrub desert. 4. Scattered globose aggregate-scrub. 5. Scrub with scattered *Metrosideros* trees (= tree line vegetation). 6. Open *Metrosideros--Sophora* forest with scrub-matrix. 7. Globose, tall-scrub with *Acacia koa* colonies and grass-matrix (= mountain parkland). 8. *Acacia koa--Sapindus* savannah. 9. *Acacia koa--Sapindus* forest with mixed small-trees and arborescent shrubs. 10. Open *Metrosideros*--lichen forest with native low-shrubs. 11. Open *Metrosideros--Gleichenia* forest. 12. Closed *Metrosideros--Cibotium* forest.

May 23, 1971

CIRCULAR LETTER TO HAWAII IBP PARTICIPANTS

Dieter Mueller-Dombois, Scientific Coordinator

From the reports and summaries given prior to and at the last workshop meeting on May 6, 1971, we now have a fairly good indication as to your participation in the Mauna Loa Transect study.

However, there are considerable problems in correlating the distributions of different organisms groups. For example, many of the smaller life forms, such as fungi, algae and insects may give a realistic altitudinal variation only if sampled with respect to a specific substrate type that you have to decide on. Secondly, there is the problem of number of sampling places that one needs to present meaningful distribution-abundance curves. Thirdly, there appears to be a definite advantage, if not necessity (in the case of the smaller life forms), to sample in the same locations as for the larger life forms (i.e., see plants, birds and mammals).

One of my main concerns at the last workshop meeting was a further clarification as to the questions that we may ask and answer with the Mauna Loa Transect study. For this reason I discussed the topic of environmental gradient analysis with respect to Whittaker's recent treatments. I briefly elaborated on the four hypotheses of organism distribution that he very clearly stated in his 1970 textbook (see below). These relate directly to the hypotheses stated in our funded IBP proposal, where the point was made that the Hawaiian biota appear to display a considerable measure of co-evolution.

Co-evolution implies that many of our endemic biota are highly specialized in adjustment to the major community-structure forming organisms. For example, when a native forest is cut and replaced by exotic tree species, we have noted that the other native biota are also destroyed to a large measure and do not reinvade the exotic tree plantation.

A high measure of co-evolution would imply a high degree of dependency, interaction and correlation in distribution. The degree of correlation in distribution is what we can test as the first step in the Mauna Loa Transect analysis.

Following is a review of environmental gradient analysis that I put together as part of a chapter on ecological field analyses for a textbook on vegetation ecology (soon to be published). Therefore, the information is presented here with this reservation.

10.6 Environmental gradient analysis

10.6.1 The concept

The concept of environmental gradient analysis does not differ in principle from the previously discussed approaches of ecological species group derivation and ecological classification. All three relate to the analysis of species and community distribution along known environmental gradients. The approach from environment to floristic analysis has been distinguished in a recent review paper by Whittaker (1967) as <u>direct</u> gradient analysis. The approach through patterns formed by the vegetation itself is called, by Whittaker, <u>indirect</u> gradient analysis. The latter does not differ in principle from the community classification by means of differential species groups or the ordination of vegetation samples by community correlation coefficients or similarity indices. In the latter approach, the floristic pattern evaluation comes first. Thereafter, an attempt is made to interpret the floristic patterns in terms of environmental relations. In <u>direct</u> gradient analysis, the environmental variation is known at the start. The floristic variation is then correlated to find out to what extent the known variation of environment is also the cause for the floristic variation encountered. Therefore, environmental gradient analysis contributes greatly to elucidation of the underlying causes of plant and community distribution. Although, cause and effect relations at finer levels of plant distribution are difficult to establish through field observations because plant to plant interactions, animal browsing or grazing, fire and other superimposed factors often obscure direct relations to known environmental factor intensities. The cause of these finer patterns can only be determined through experimentation (see

10.6.2 The technique

The basic question in environmental gradient analysis asked by Whittaker (1967, 1970) is, "How are species populations distributed in relation to one another and communities along an environmental gradient?"

As an example, consider an altitudinal gradient upslope along a mountain side that shows more or less clear vegetation belts or zones. Whittaker's approach has been to sample such an altitudinal gradient at predetermined elevational intervals by quadrats along transects. In forest and heath vegetation (Great Smoky Mountains, 1956; Siskiyou Mountains, 1960) he used 20 x 50 m quadrats. These were laid out at 50 m or 100 m altitudinal intervals. Commonly, he used five or more such quadrats for an elevational interval of 100 m. In the quadrats he enumerated all trees and shrubs. Herbs were assessed in terms of frequency in each of these quadrats by twenty-five placements of a 1 m^2 frequency frame. The results of the five or more quadrats were combined for each elevational interval. The result of these composite samples were then plotted in relation to the elevational gradient. The distribution of each quantitatively more important species was expressed by its range and by its change of quantitative importance along the gradient. The distribution range was plotted along the abscissa, which showed the elevational gradient. The quantitative shift of the species along the elevational gradient was usually expressed in relative or percentage values (e.g., number of individuals of a tree species over number of individuals of all tree species at that elevation). These quantitative values were plotted as y-values (ordinate) over the x-axis (the environmental gradient).

The diagrams produced in this way show a series of belt-shaped species curves. The characteristics of these species curves are that they show each an individual position with regard to curve peak (mode) and range. The species modes differ from one another by position along the x-axis (=elevation) and by height above the x-axis (=quantitative importance). None of the species portrayed by Whittaker show closely similar distribution ranges. Moreover, hardly any of the species show closely coinciding positional modes along the elevational axes.

10.6.3 Conclusion

From his studies of species distributions along environmental gradients done in this manner, Whittaker (1970, p. 37) draws two conclusions (quote):

"1. Each species is distributed in its own way, according to its own genetic, physiological, and life-cycle characteristics and its way of relating to both physical environment and interactions with other species; hence no two species are alike in distribution.

2. The broad overlap and scattered centers of species populations along a gradient imply that most communities intergrade continuously along environmental gradients, rather than forming distinct, clearly separated zones. (Either environmental discontinuity or disturbance by fire, logging, and so on, can, of course, produce discontinuities between communities.)"

(end of quote)

With this conclusion, Whittaker clearly supports and reemphasizes the concept of species and community individuality of Ramensky (1930) and Gleason (1926). Moreover, he has come to the same conclusion as Curtis and his collaborators of the Wisconsin school of the continuum. Whittaker arrived at this conclusion through direct gradient analysis, the Wisconsin workers primarily through indirect gradient analysis.

10.6.4 Unresolved questions

However, basic questions remain unresolved:

(1) How is it possible that so many vegetation ecologists have come to the conclusion that species groups can be recognized that have closely similar distributions in nature?

(2) How is it possible to recognize vegetation belts along an altitudinal gradient, for example, if there are only overlapping ranges of species distributions?

(3) How can one explain the often abrupt change in vegetation structure in an altitudinal zonation from forest to scrub, the often marked zonation of herb-shrub-trees on a uniform coastal dune substrate or the marked zonation on salt flats or other habitats where the environmental gradient does not change abruptly, but the vegetation structure does?

The existence in nature of the phenomena mentioned under the third point is well documented in many studies, and was recently newly clarified by Daubenmire (1966, 1968, p. 18). Whittaker and others (e.g., McIntosh, 1970) apparently deny this phenomenon as having any reality.

The second question above remains unresolved in Whittaker's (1970) latest treatment.

The first question is answered in part by Whittaker himself. He says that groups of species (or communities) can only be recognized arbitrarily. This is true. But the answer is unsatisfactory, because it evades the real question. "Arbitrary" is too general a word for the phenomenon that some species have more closely coinciding distribution ranges (though not exactly coinciding ones) along specific environmental gradients than others. It does not matter that the degree of similarity or dissimilarity of distribution ranges is continuous in principle.

Whittaker (1967) does not deny the existence of ecological groups of species. But he defines them as species that have closely coinciding modes along a specific environmental gradient. Therefore, their ranges may be broadly overlapping. Also, Whittaker's ecological groups may be species of different life forms. Therefore, trees, shrubs, and herbs may form one ecological group. This is in clear contrast to the ecological group concept of Ellenberg, who defines them as species of closely similar life forms growing together in the same habitat and showing closely similar distribution ranges with regard to a specific environmental gradient.

It is, of course, more likely to find species with closely similar distribution ranges among combinations of different life forms. The clearest case of such closely coinciding distributions are host-parasite relationships. But the degree of complementation and interdependency among species should, in principle, vary continuously among different life forms and species.

It is hard to understand how one viewpoint of non-correlation of species ranges should be the answer to the question of species and community distribution in nature. Certainly it would be equally dogmatic to claim correlation of species ranges as the only true expression of community development in nature. However, such close correlations can be expected also, and there seems to be no good reason why the two forms of species distributions cannot coexist as facts in different situations. It is for future research to decide what patterns of species correlations apply to particular groups of organisms and life forms and to particular areas and environmental gradients.

10.6.5 Four hypotheses

Whittaker (1970, p. 35) presents four distinct hypotheses to this problem. These are (quote):

"1. Competing species, including dominant plants, exclude one another along sharp boundaries. Other species evolve toward close association with the dominants and toward adaptation for living with one another. There trees develop distinct zones along the gradient, each zone having its own assemblage of species adapted to one another, and giving way at a sharp boundary to another assemblage of species adapted to one another.

2. Competing species exclude one another along sharp boundaries, but do not become organized into groups with parallel distributions.

3. Competition does not, for the most part, result in sharp boundaries between species populations. Evolution of species toward adaptation to one another will, however, result in the appearance of groups of species with similar distributions.

4. Competition does not usually produce sharp boundaries between species populations, and evolution of species in relation to one another does not produce well-defined groups of species

with similar distributions. Centers and boundaries of species populations are scattered along the environmental gradient."

The above four hypotheses were quoted in full because they are perhaps the clearest statements recently presented on this problem.

All four seem possible: The first in species-poor areas, where each synusia in a community is represented by only few species, perhaps by only one, and where the parallel distribution ranges relate to species of different life forms or different sociological value (sensu Daubenmire, 1968). Here, one such integrated unit (=community) competes with another such integrated unit of complementary life forms. Each species of parallel life form excludes the other by competition. This situation of all synusiae replacing each other at the same point along an environmental gradient is, however, unlikely to recur at several points with such precision as suggested in hypothesis 1.

The second hypothesis may find reality also in species-poor areas where the synusiae consist of only a few or one species. But here the different life forms or synusiae are not well integrated. Each synusiae has its individuality of distribution. For example, an undergrowth fern synusia may extend beyond the limits of the forest overstory into a neighbouring scrub community. Where the fern synusia meets a grass synusia there may be a sharp boundary along the gradient. Such distributions have been observed also.

The third hypothesis postulates correlated modes of species distribution (="ecological groups", sensu Whittaker, 1967), but overlapping ranges. The correlated modes are most likely to be found among species of different life forms that do not compete with one another for the same niche. Such distributions have been observed by many investigators.

The forth hypothesis is the one of non-correlation in species modes and distribution ranges. Whittaker has demonstrated this "individualistic" pattern of species distribution with data from several areas. Therefore, he holds to the view that this is the only realistic pattern in nature. His ecological group concept is thus clearly only a marginal idea as it is only explained by the third hypothesis.

10.6.6 Application to evolution

It is clear that the question of species and community distribution is not yet closed with an acknowledgement of only one of the four hypotheses as portraying a realistic trend.

Further research into this question is important as it has a great bearing on the evolution of species interactions, the evolution of communities and ecosystems. Whittaker (1967, 1970) holds that the highest degree of integration is accomplished by a high beta-diversity. This means accommodation of a large number of species with restricted distributions along an environmental gradient, as opposed to few wide-ranging species on the same gradient. The term beta-diversity is understood as a contrast to alpha-diversity, which refers to the number of species in a given community.

Whittaker believes that the trend in natural selection and plant evolution has gone away, rather than towards the formation of species with parallel distributions. This is an interesting thought. But an increase in floristic richness on a given environmental gradient leading to narrower distribution ranges of most species involved, may also be accompanied by life form complementation and thus may not necessarily result in a tendency toward greater overlap in distribution ranges.

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APPLICATION

The following sheet (Fig. 1) showing 12 established sampling points (or vegetation samples = relevés) along the Mauna Loa Transect plus 7 additional ones under Variations was distributed already at the May 6 meeting. Added here are only the altitudinal limits of the transect segments 2 through 8. The transect segments, as you know, are the ecosystem types as described in the 1966 "Atlas for Bioecology Studies in Hawaii Volcanoes National Park."

I wish to recall here that the relevés are only established on the oldest substrates along the Mauna Loa East Flank Transect. The more recent lava flows were purposely omitted. There are a few additional relevés on more recent flows, but they are not included here. Also, in establishing your own sampling points, you should keep this in mind.

I now would like to go one step further into the application of the sampling procedure.

For the plant ecological analysis, we have decided to subdivide the altitudinal gradient from 4,000 to 10,500 feet into 500 foot intervals and to expand the number of relevés to 3 for each altitudinal interval and main life form group.

FIGURE 1. MAUNA LOA TRANSECT ANALYSIS

Each participant should include first the basic sampling plots, then he may add others. A minimum is 12 sampling points:

Relevé	Elevation (ft.)	Ecosystem	Variations
			Sav. Forest (Kipuka)
20	4,000	Savanna (segment 8) 4 - 4,500'	19 39 62 (segment 9)
40	4,400		
			Koa Grass Scrub
21	5,200	Parkland (segment 7) 4.5 - 6,600'	21 22 23
24	6,200		24 26 25
17	6,800	Open subalpine forest-scrub (segment 6) 6.6 - 7,500'	60% cover
16	7,000		↓
15	7,600		30% cover
11	8,000	Tree line scrub (segment 5) 7.5 - 8,100'	with trees 11 aa; 14 pahoehoe
14	8,200		without trees 12 aa; 13 pahoehoe
43	8,500	Alpine scrub (segment 4) 8.1 - 8,500'	10% cover
44	9,200	Alpine scrub (v. sparse) (segment 3) 8.5 - 10,000'	2% cover
45	10,000	Moss desert (segment 2) 10 - 11,000'	.1% cover

Figure 2 shows the interval numbers 1-13 in relation to elevational range (in 1,000 feet). Thus, interval #1 = 4 - 4.49 thousand feet, interval #2 = 4.5 - 4.99 thousand feet, etc. Also shown are the transect segment numbers and names in relation to elevation.

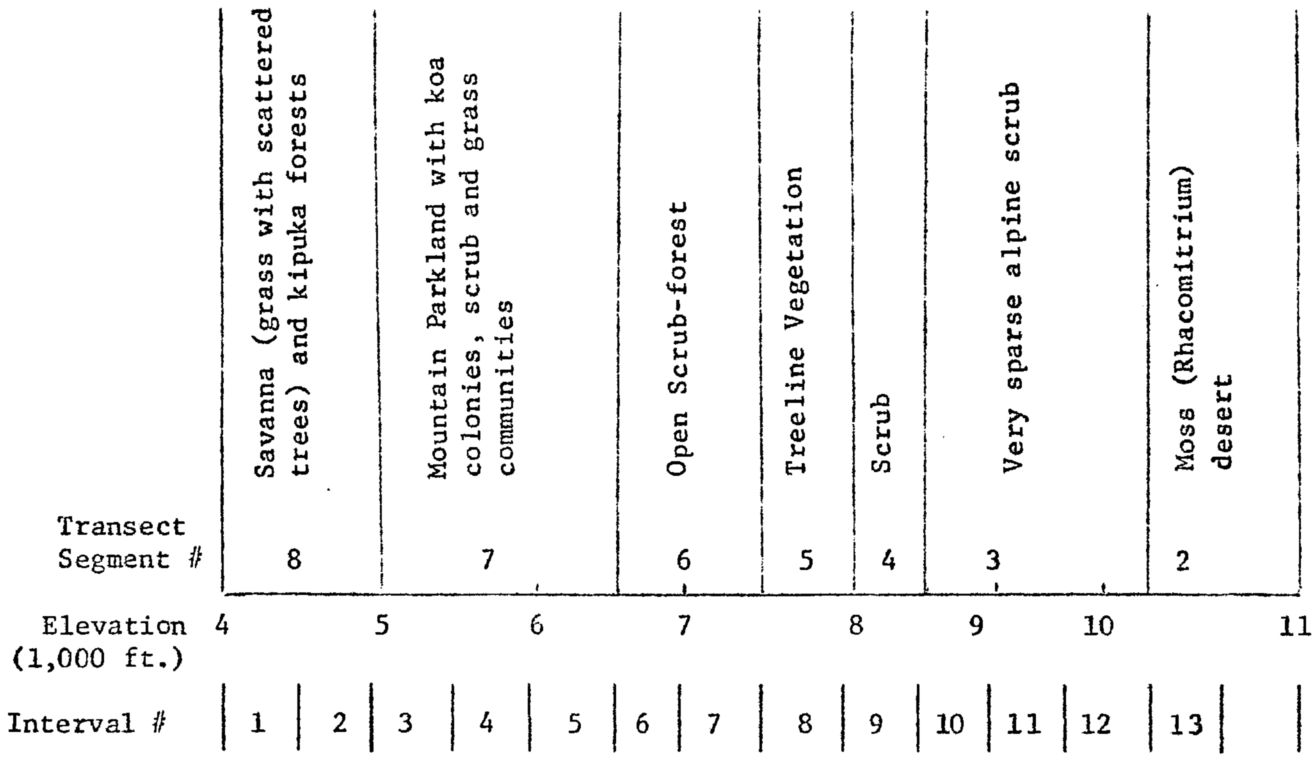

FIG. 2. Showing the relation of elevation, transect segments and interval numbers for sampling the upper Mauna Loa Transect (from 4,000 - 10,500 feet elev.).

The concept of "main life form group" is here defined very broadly to incorporate everyone's idea of how he sees best fit to group his species lists into the most appropriate life form classes.

For the plant ecological analysis, a 4-way break-down into life form communities seems appropriate. We intend to name these: (1) tree communities, (2) shrub communities, (3) grass communities, (4) moss communities. Within these we may distinguish synusiae (= species of the same life form growing together). But the 4-way break-down may be least ambiguous for the other biologists on the IBP team.

ANALYSIS IN FORM OF TWO-WAY TABLE

Since we have transferred all 62 relevés done so far in the Park to the computer, we are now arranging the 21 already established relevés on the upper Mauna Loa Transect by computer into a two-way table.

The format will be as follows:

SPECIES ALTITUDINAL GRADIENT
Interval number

SPECIES	1			2			3			etc.
Relevé #	62	39	__	__	__	__	21	__	__	
Life form group										
(1) Tree communities										
Height layer A										
Species a	.	.					.			
b	.	.					.			
c	.	.								
etc										
Height layer B					SPECIES QUANTITIES					
Species a	.	.								
b	.	.								
c	.	.								
etc.										
Other height layers										
Relevé #	__	__		__	__	__	23	__	__	etc.
(2) Shrub communities										
Structural layer, etc.										
Species a							.			
b							.			
etc.										
Relevé #	19	20	40	__	__	__	22	__	__	etc.
(3) Grass communities										
Species a	.	.	.				.			
b	.	.	.				.			
etc.										

The important feature of this two-way table is its flexibility. In the left hand column are the species listed under appropriate life form categories. Any number of other life form category and species can be added. Across the table head are the altitudinal intervals with always 3 spaces beneath. Only some of these are filled with relevés so far. There are a number of empty spaces. These, we try to fill up this summer with additional vegetation samples.

The species quantities are recorded in the body of the table. We intend to use percent cover for all plant life forms, but density and frequency values would fulfill the same purpose.

The distribution ranges of each species will be shown automatically by the spread of quantitative values across the table (= altitudinal gradient). At the moment, the number of relevés is too small to show any valid curve trends of species distribution and abundance along the environmental gradient.

However, when the gaps are filled with additional data, we will obtain sufficient information for a correlation analysis of species distributions and modes.

FURTHER STEPS

Once the species ranges and peaks are analyzed for all organisms that have been sampled along this altitudinal gradient, we will have data to demonstrate the degree of interaction among the biota.

The next question then will be to determine clearly the nature of this interaction for each major species and life form group. At this point, the interaction models that we have been talking about will be changed from merely ideal structures to realistic structures in relation to the major environmental changes along this altitudinal gradient.

PARTICIPATION

Following is what I would consider an ideal participation in the Mauna Loa Transect study. It should be possible to obtain meaningful distribution-abundance curves along the elevational range from 4,000 to 10,500 feet for the various life forms on which we have put the stress in our program. Broadly defined, these may be listed as:

Botanical organisms
1. Woody plants
2. Herbaceous plants
3. Mosses
4. Lichens
5. Algae
6. Fungi

Vertebrates
7. Birds
8. Mammals

Invertebrates
9. Drosophilidae
10. Diptera
11. Homoptera
12. Heteroptera
13. Sciaridae
14. Soil inhabiting arthropods and mites
15. Litter inhabiting ants, coleopterons scavengers
16. Bark inhabiting cerambycid beetles

17 Others

September 21, 1971

MEMORANDUM

TO: IBP Participants

Botany
G. E. Baker
M. Brown
C. A. Corn
M. S. Doty
D. C. Friend
C. H. Lamoureux
D. Mueller-Dombois
G. O. Spatz
R. Becker (Grad. Asst.)
R. Cooray (Grad. Asst.)
P. Dunn (Grad. Asst.)
L. McGurk (Grad. Asst.)
B. Furmidge (Site Manager)
T. Herat (Plant Identifier)
L. Matsunami (Technician)
J. Craine (non-salaried)
R. Gay (non-salaried)
J. Porter (non-salaried)

Entomology
J. W. Beardsley
C. J. Davis
M. Delfinado
W. Gagné
J. L. Gressitt
F. H. Haramoto
D. E. Hardy
F. Howarth (Technician)
J. Jacobi (Technician)
T. Nishida
F. J. Radovsky
G. A. Samuelson
W. A. Steffan
M. Conant (Grad. Asst.)
J. Leeper (Grad. Asst.)
L. Nakahara (Grad. Asst.)

Vertebrates
A. J. Berger
R. E. MacMillen
P. Q. Tomich

Genetics
G. C. Ashton
H. L. Carson
M. P. Mi
Y. K. Paik
S. Yamashiro
W. Steiner (Grad.Asst.
K. C. Sung (Grad.Asst.

Microenviron. Anal.
P. C. Ekern

Agric. Engineering
T. Liang

FROM: D. Mueller-Dombois

SUBJECT: Workshop Symposium, October 8, 1971 (Friday, whole day)
9:00 a.m. - 5: 30 p.m. in Bishop Museum Conference Room
4th Floor

Agenda
Current business
Report on Dallas Meeting

Program (see objectives below)

A. Kilauea Montane Rain Forest Study
Chairman: A. J. Berger

9:30 Tree population structure and dynamics. Ranjit Cooray (15 min.)

9:50 Spatial pattern of plant synusiae. Jean Craine (15 min.)

10:10 Progress report on small mammals. P. Quentin Tomich (10 min.)

10:30 Foliar insects on Koa and Ohia trees at four sampling points. Wayne Gagne (10 min.)

SHORT COFFEE BREAK

11:00 Sciaridae: Comparison of two sampling sites within the forest and with a Koa stand on Mauna Loa. W. A. Steffan (15 min.)

11:20 Hawaiian Drosophila: A comparison of Kilauea and Olaa Forests. H. L. Carson (10 min.)

11:35 Variation of phyllosphere fungi. Gladys E. Baker (15 min.)

11:55 Koa growth rates in relation to age. Guenter Spatz (20 min.)

LUNCH BREAK

B. Mauna Loa Transect Study
Chairman: J. L. Gressitt

1:30 Gradient analysis of vascular plant communities. D. Mueller-Dombois (20 min.)

2:00 Foliar insect communities between 4,000 and 7,000 feet. Wayne Gagne (10 min.)

2:15 Distribution of an introduced koa-psyllid along Mauna Loa transect from 4,000 - 7,000 feet. J. W. Beardsley and John Leeper (speaker) (10 min.)

2:30 Arthropod communities on Metrosideros from sea level to 7,000 feet. T. Nishida, F. H. Haramoto (speaker) and L. Nakahara (15 min.)

2:55 Phenological observations on woody plants. J. Porter and C. H. Lamoureux (20 min.)

3:25 Koa germination study. Guenter Spatz (15 min.)

COFFEE BREAK AND GROUP DISCUSSIONS

C. Mauna Kea Transect Study

4:00 Gradient analysis of insect communities along Wailuku Stream. E. Hardy and M. Delfinado (20 min.)

D. Species Variation Studies

4:30 Variation in Metrosideros. Carolyn Corn (15 min.)

4:50 Variation in Metrosideros. William Steiner (10 min.)

MEETING SHOULD END BY 5:30 p.m.

I would like to emphasize that this workshop symposium is an informal meeting, in which one objective is to inform each member in our group about what each of us has been doing so far. Input during discussion-periods is valued just as much as the reporting itself.

A second, but no less important, objective is a reorientation on our goals as a major integrated research program of the US-IBP. Remember that we have to demonstrate integration of results to obtain continued funding.

Guests are welcome, although presence of a non-participating audience is not emphasized at this time. However, invitations for participation will be sent to Mr. Gene Kridler (Director, U.S. Bureau of Sports, Fisheries and Wildlife), the new superintendent of Hawaii Volcanoes National Park, Mr. Bryan Harry, also to Don Reeser, Ken Baker and Win Banko, who have shown much interest in our program. Also, Mr. Norman Carlson, Bishop Estate Forester, will be invited. He is the person who suggested the Kilauea Forest Study and provided access to this major research site.

A 35 mm slide projector and an opaque projector will be provided, also coffee during the breaks.

Natural History of *Toxoplasma gondii*

Gordon D. Wallace

Pacific Research Section
National Institute of Allergy
and Infectious Diseases

The protozoan parasite, *T. gondii* has been known for years to commonly infect a variety of homoiothermic animals including man, and to occasionally cause severe disease and death. The basic methods by which the parasite is maintained and transmitted in nature, however, have not been elucidated. Current epidemiologic and experimental data suggest the following working hypothesis: felids are the definitive hosts of the parasite, small homoiothermic animals such as rodents and birds are intermediate hosts, and certain coprophagic insects such as flies, cockroaches and beetles are transport hosts.

The Kilauea Rain Forest and Maunaloa Transect studies offer an excellent opportunity to define ecosystems in which the parasite is propagated, or not propagated, whatever the case may be. Small wild mammals such as rats and mongooses can be used as indicators of the prevalence of *Toxoplasma*, by testing their blood for the presence of specific antibody.

Blood specimens from 32 rats (*Rattus rattus*), 3 mice, and one mongoose collected from Kilauea Rain Forest since April 24, 1971 have been tested for *Toxoplasma* antibody. Of these one rat and one mongoose, caught on the same date in the same trap line were positive. However, the data are yet too few for any conclusions.

November 7, 1971

Report on Oakridge Meeting, Nov. 4-6, 1971

The meeting consisted of three parts:

A. The 1971 annual meeting of the US/IBP National Committee (Nov. 4 and 5)
B. A joint meeting of IBP Directors with the IECP committee (evening, Nov. 5)
C. A meeting of the IBP Biome Directors (Nov. 6)

A. US/IBP National Committee Meeting

This two-day meeting took place at the Oakridge National Laboratory (Tennessee), which is the home-base of the Deciduous Forest Biome. The meeting was attended by 35 members, including the US National Director of IBP, Frank Blair, representatives of the National Academy of Sciences (Dick Oliver, Sam McKee), members of the Central Office of the US/IBP from Austin, Texas (Bill Milstead, Norris Loeffler), the directors or alternates of the programs in the Environmental (EM) Component, and the directors of the Human Adaptability (HA) component of IBP.

The main agenda items were:

1. US/IBP Progress Report #5 for next year (FY 73)
2. FY 73 Budget Information
3. Future of US/IBP
4. Fifth General Assembly of IBP, Seattle August 30-Sept. 7, 1972.
5. Field Trip

1. Report #5

Each participant was handed a copy of Report #4, entitled "Research Programs Constituting U.S. Participation in the International Biological Program" (1971, 121p.). This report, which is bound in a red cover, will be distributed to each IBP participant within the near future together with the 1971 Directory through the IBP office at the National Academy. Report #4 contains a distillation of the progress of each individual US/IBP program. It is not a report of scientific results, but merely informs generally on concepts and progress up to Spring 1971. At that time our ISLAND ECOSYSTEMS program had just begun, and Report #4 contains abstracts of a short progress report on the Hawaii IBP that I submitted to the National Academy of Sciences in February 1971. According to Dick Oliver (Secretary of US/IBP at the National Academy of Sciences) Report #4 has been very effective in obtaining congressional approval for the FY (Fiscal Year) 72 funds.

Report #5 is planned to present a degree of further integration of all ongoing US/IBP research. The chapter outline was discussed. A tentative agreement was reached. Each IRP (Integrated Research Program) director is to submit his contribution to Report #5 by December 1, 1971.

2. FY 73 Budget Information

Each IRP director had to submit budget estimates for FY 73 and Fy 74 during the meeting. No guidelines were given this year as to the amount of funds we may realistically expect for FY 73. In addition, each IRP director was asked to make a close guess as to the distribution of funding sources he expects, including NSF. Following is a breakdown of our past, present and anticipated future funding as declared by me during the budget session for the Island Ecosystems (Hawaii) Program:

	Total	NSF	USDA[1]	USDI[2]	Industry[3]
FY 71	$245,000	240,000	-	-	5,000
FY 72	430,000	423,000[4]	-	-	7,000
FY 73	700,000	450,000	90,000	150,000	10,000
FY 74	700,000	450,000	90,000	150,000	10,000

[1] US Dept. of Agriculture
[2] US Dept. of Interior
[3] Industry here means Bishop Estate
[4] Includes Drosophila Project

3. Future of US/IBP

This was the topic also of the Dallas Meeting (Sept. 27, 1971) about which I reported briefly at the last Workshop Symposium on October 8. As you know, the IBP will end officially in 1974. Problems about the future fall into two categories: conceptual and organizational.

Conceptual Developments

Each IRP director was asked about his views on the future of his regional program. Except for one, all expressed a desire to continue the program beyond 1974. The exception was Otto Solbrig (Harvard) who directs the Desert and Mediterranean Scrub programs. Solbrig said, that he anticipated finite objectives particularly for the Desert Scrub program that the questions asked for these objectives will be answered in the course of the program and that he sees no need for continuation afterwards. In contrast, the need to continue the programs beyond 74 was emphasized by all others. Most said that they were just getting started and that new questions tended to come forth as they progressed. The new orientation evolving is towards a greater consideration of man as a factor in the environment, towards a modification of the biome concept to include variously man-modified and man-dominated ecosystems and all significant ecosystems of a larger region. All biomes work towards more validation in the sense of regional comparisons. For example, the Desert Biome (under Dave Goodall) is establishing validation sites in Tunisia, Israel and India (Tar Desert) with PL 430 funds. Similar developments are underway in the other biome programs. I pointed out that we see our future development in two directions: (a) Intensification from our present approach of biota evaluation in terms of sociological ecology (i.e., species recording, assessment of their quantities in time and space, study of their interactive functions) to process ecology (i.e., the study of ecosystem metabolism); (b) Transfer of our activities to other sites, transects and islands. I pointed out that our present sites are not yet representative of the Hawaiian Islands as a whole. As a further concept, I elaborated our aim of joining ecological studies of communities with evolutionary studies of species populations to eventually come to an interpretation of the evolutionary development of ecosystems. In contrast to the mainland ecosystems studies, our program is accepted as unique, if we are able to come up specifically with contributions to island ecosystems evolution.

Organizational Development

A major prediction made during the conference was that INTERNATIONAL RESEARCH PROGRAMS (IRP's) are here to stay. However, there is no attempt to transfer any of the US/IBP programs into a new super-organization, unless the individual IRP's demonstrate a strong capacity for survival as IRP's. It was predicted that a few programs will probably dissolve, but that some (particularly the major Biome programs) will most certainly survive. I would like to have some input on your part whether you think it desirable or not that the ISLAND ECOSYSTEMS IRP should be planned for survival beyond 74.

Much time was spent on discussing what structure could replace IBP. One/ possibilit is to abandon any coordinating structure for the various US/IRP's. This alternative would make sustained funding very improbable. A new international-intergovernmental structure would be the emerging UNESCO program "Man and the Biosphere" (MAB). Planners of this program hope to inherit IBP. However, MAB cannot be expected to serve as a funding agency, because it is merely a United Nations program. Therefore, connection with MAB will be sought, but not as a funding agency. NSF will probably remain the primary funding agency. It was thought expedient not to seek a Federal Governmental structure. The reason for this is to preserve independency. The recently formed Institute of Ecology (TIE) was thought to be the best probable future umbrella. This is a non-governmental US research organization that is just emerging as an institute promoting integrated ecosystems research. Steps were initiated to explore these possibilities further.

4. Fifth General Assembly of IBP

This will be the last general assembly of IBP which will take place in Seattle next summer (August 30-September 7, 1972). There will be two general symposia at this meeting (a) Productivity and (b) Human Adaptability. The scientific input of the Hawaii program to the Seattle meeting will be very limited as we have little going on as yet under (a) and nothing under (b). However, we were urged to contribute with an exhibit depicting significant phases of our Island Ecosystems program. What we could contribute is perhaps a slide show with recorded voice. Professor Nishida's and Dr. Haramoto's "show" of October 8 would be a good example. We could also present a large colored chart of the Mauna Loa ecosystem transect with ribbons going to interesting ("eye-catching") research activities and results in form of photographs, display boxes, etc. Please give this some thought. This is very important. A film for educational purposes is planned for the Coniferous Biome. I have invited the Public Relations Group of IBP to make a similar film about our Hawaii program in the anticipation that such a film may help greatly in the conservation problems of the Hawaiian Islands.

5. Field trip

The afternoon of Nov. 5 was spent on a field trip to some research sites of the Deciduous Biome at Oakridge. Several half-hectare forest stands are intensively investigated and instrumented for environmental measurements and research on primary and secondary production and decomposition. Among the instrumented components shown were CO_2 uptake research facilities. A lift-truck is used that can position the researcher with a gas-analyser into any desired section of the crown-canopy. A 30 m high instrument tower was established for radiation measurements, foliage increment analysis and insect sampling. Very impressive was the Oakridge Watershed study. Here two weirs give continous records of stream outflow. One of the regional objectives is to measure the absorptive and recycling capacity of the deciduous forest for airborne and precipitated industrial pollutants. Therefore, water quality is continually monitored in the experimental watershed. Also, experiments with induced pollutants are underway.

B. Joint meeting with IEPC committee

IEPC stands for International Environmental Protection Committee. The committee is known also as the Malone committee. It is comprised of 4 members of the National Academy of Sciences (T.F. Malone, David Gates, F. E. Smith, Nathaniel Wollman). The IEPC is a recently established National Academy committee of considerable political influence involved in promoting US and International research in the environmental sciences. The committee was on its way to a MAB conference in Paris, where preparations are being made for the 1972 Man and Environment meeting in Stockholm. The IEPC committee is concerned with the future of the US/IBP and will consider future sponsorship of selected IBP research.

C. Meeting of IBP Biome Directors

Although Hawaii is not one of the Biome programs, I was invited to participate. At the Dallas meeting (Sept. 27), a restructuring of the six US biomes was decided by vote. The reason for restructuring was to increase interbiome coordination to achieve better calibration of research and results. Only 5 of the 6 Biomes are presently funded. The sixth Biome (The Tropical Forest Biome) has only received a planning grant for submitting an integrated proposal which may be presented early next year by H. T. Odum. In addition to the five Biomes, there are four other IRP's (Upwelling Ecosystems, Desert Scrub, Mediterranean Scrub and Island Ecosystems). Only Island Ecosystems was presented, and our program is now considered for a joint coalition with the five Biomes. We will retain our independent approach but may join in the following coordinated activities, the first of which has already become a reality:

1. Specialists meetings
2. Staff rotations
3. A common Newsletter
4. Data dissemination and information center
5. Public information programs
6. Conceptual development group in ecosystems analysis
7. Modeling
8. International coordination
9. Research designs of man-influenced systems
10. A ten-year research plan

Each of the above 10 points (plus 4 others not worth enumerating here) received detailed discussions of pros and cons. The main emphasis was negative to a centralized directorate of all US ecosystems programs; instead, however, a coalition with some centralized activities, such as the above is sought. The final form of restructuring will be decided in a follow-up meeting (probably end of January '72). At that time, it will be decided in what structure the Environmental Component of the US/IBP will be transferred to a sponsoring organization (probably TIE) in 1974.

Attached is a press release (only for principal investigators) informing further of the above developments.

D. Mueller-Dombois

Attachment

September 7, 1971

MEMORANDUM TO: IBP Participants

Botany
G. E. Baker
M. Brown
C. A. Corn
M. S. Doty
D. C. Friend
C. H. Lamoureux
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R. Becker (Grad. Asst.)
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J. L. Gressitt
F. H. Haramoto
D. E. Hardy
F. Howarth (Technician)
J. Jacobi (Technician)
T. Nishida
F. J. Radovsky
G. A. Samuelson
W. A. Steffan
J. Leeper (Grad. Asst.)
L. Nakahara (Grad. Asst.)

Vertebrates
A. J. Berger
R. E. MacMillen
P. Q. Tomich

Genetics
G. C. Ashton
H. L. Carson
M. P. Mi
S. Yamashiro
W. Steiner (Grad. Asst.)
K. C. Sung (Grad. Asst.)

Microenviron. Analysis
P. C. Ekern

FROM: Dieter Mueller-Dombois, Scientific Coordinator

SUBJECT: Miscellaneous Items

1. Our revised second-year budget of August 9, 1971 has been approved as it stands. I received a phone call from Dr. J. M. Neuhold, NSF, Washington, D. C., to this effect. Dr. Neuhold is the new Director of Ecosystem Analysis, replacing Dr. C. F. Cooper this year. A formal letter of approval of our second-year budget will arrive soon.

2. A new development in the US IBP is the establishment of so-called "specialists committees." The purpose of these committees is to coordinate work across the individual programs in particular areas. I have sent in the names of people on our programs that seemed to best fit the established areas:

(1) Storage and retrieval	M. P. Mi (Sandra Yamashiro)
(2) Modeling	M. P. Mi (Mrs. Ruth Gay)
(3) Phenology	C. H. Lamoureux (John Porter)
(4) Nutrient cycling	we have as yet no program in this area
(5) Decomposition	G. E. Baker (D. J. C. Friend)

(6) Meterology	P. C. Ekern
(7) Consumer processes	M. Delfinado (Frank Radovsky)
(8) Primary productivity	D. J. C. Friend (R. Becker - a new Ph.D. student in botany)

3. A further new development along the same line is a rethinking in the Biome IBPs on the aspect of comparing their studies from biome to biome. So far, much stress had been given to intensification of within-biome research, but the aspect of comparability had been more or less neglected. In this new orientation, the Origin-and-Structure-of-Ecosystems-Subprograms, of which Hawaii IBP is one, are pulled in. A meeting on this new orientation will be held in Dallas on September 26-27 at which I was invited to participate.

4. We should now plan for a workshop meeting in early October. I have already discussed this point with A. Berger and J. L. Gressitt. It would seem appropriate to hold the next workshop meeting as an informal symposium, where individual subprojects may be discussed as to their results obtained so far.

I am thinking of 15-20 minutes long presentations by IBP members with subsequent discussion periods of 5-10 minutes. Perhaps we should take a full day or half-a-day for this next meeting.

If you intend to speak about the results of your program obtained thus far, please indicate so and give your topic and time-length you will need to Lynnette at 944-8044 by September 20. Also, please indicate what day of the week would suit you best for this next workshop.

Immediately after September 20, I will set up a program and time. The meeting should preferably be held in the week of October 4 to 8.

October 20, 1971

MEMORANDUM

TO: IBP Participants, Hawaii Terrestrial Biology Subprogram

FROM: Charles H. Lamoureux

SUBJECT: Report on meeting of Phenology Committee

The U.S. National Committee for the IBP has established a number of specialist committees to bring about closer communication between the various biome projects and between the biomes and other IBP ecosystems studies. One of these, the Phenology Committee, met in Denver on October 16 and I represented the Hawaii Subprogram at this meeting.

We reviewed the present IBP phenology activities in the grasslands, deciduous forest, desert, and tundra biomes and in the Hawaii subproject, as well as phenological projects of the U.S.D.A. and of the Wisconsin Phenological Society. Dr. Forrest Stearns presented preliminary plans for a Phenology Symposium to be held at the AIBS meetings in Minneapolis next August.

Much of our time was spent in discussion of ways in which collection of phenological data could (or even if it should) be made more uniform among biome and ecosystem studies. While the committee realized that it would be neither possible nor necessarily desirable to collect the same kinds of data in all studies, we do hope to devote our next meeting to an attempt to develop some guidelines which would be applicable to all study areas.

In order to do this, the committee needs input from investigators. Present studies emphasize phenological events in higher plants only, (with some conspicuous exceptions such as certain entomological studies which are going on in the Hawaii subprogram), and it would seem desirable to include observations on consumers and decomposers as well as producers. We need information from each of you to determine what types of phenological events should be recorded for the purposes of your studies. The committee has prepared a matrix and we would like you to complete as many portions of it as you can. Please return this to me by December 1, 1971.

Also attached is a contribution from Drs. Taylor and Sayrs of Oak Ridge who have prepared a preliminary format for storage of phenology data for the Eastern Deciduous Forest Biome project. While this format considers only deciduous higher plants from the temperate, seasonally deciduous forest, and would not be applicable in any direct way to studies in Hawaii, it is a good indication of the kinds of phenological data being recorded by some observers. Members of the Phenology Committee have been invited to direct comments directly to Dr. Taylor, and if any of you wish to do so, please respond directly to him (with a copy to me).

The committee will hold its next meeting in January at the University of North Carolina.

1. For purposes of your IBP studies, what phenological events should be recorded?

2. Give a brief definition or description of the event, so that a person who is not a specialist in your field could make a reliable observation of the event.

	PRODUCERS	DECOMPOSERS	CONSUMERS	
Begin vegetative				First appearance
Peak vegetative				Maximum numbers
Begin reproductive				Begin reproductive
Peak reproductive				Peak reproductive
Senescence				Disappearance

Return to: C.H. Lamoureux, Department of Botany, University of Hawaii, Honolulu, Hawaii 96822

By: As soon as possible, but not later than 1 December 1971.

November 17, 1971

MEMORANDUM

TO: IBP Participants, Hawaii Terrestrial Biology Subprogram

FROM: Ruth Gay, Botany Department, University of Hawaii, Manoa

SUBJECT: Summary of US-IBP Specialist Meeting in Modelling, October 15-17.

A resume of modelling activities in each of five biomes and three special projects were presented by Kent Bridges, Desert Biome; Bill Hatheway, Coniferous Biome; George Innis, Grassland Biome; Bob O'Neil, Deciduous Biome; Phil Miller, Tundra Biome; Norm Slade, Mediterranean Scrub; John Walsh, Upwelling; and Ruth Gay, Island Ecosystems.

The following intergroup activities were initiated:

a. An annotated bibliography of modelling activities with a key word index will be issued quarterly. The existing bibliography will be key worded and supplemented annually. Please forward to me bibliographic notes or xerox copies of modelling literature, published or unpublished, that you may see. Also please let me know if you want a copy of the key word index when it becomes available.

b. A register of employment applicants will be circulated among the eight groups upon permission of the applicants. A dozen resumes of prospective modellers have been sent to me thus far.

c. A directory of IBP modellers was prepared to encourage intergroup exchange of ideas. If you wish to be included in this directory, please notify me.

d. The feasibility of preparing an educational manual of eco-games based on IBP research and modelling is being investigated.

e. IBP modelling efforts will be presented in a symposium at the 1972 AIBS-ESA Meeting.

Decisions regarding future meetings:

a. Committee composition will be invariant. If one program cannot be represented by its official representative, a substitute will not be sent.

b. The next meeting will be held on the Big Island in late April or early May. The first day will be spent in visitations to field research sites and in orientation talks on Hawaiian ecology. The following four days will be devoted to developing a modelling strategy, formulating an ecosystem model and submodels, fitting submodels together, and producing simulation and sensitivity runs.

The goal of this meeting is to make concrete the various IBP views and approaches to modelling rather than exclusively to develop a guide model for the Hawaiian project. An important outcome for us, however, will be the valuable guidance and assistance to our Hawaiian modelling efforts. The other groups are willing to share their programs and mathematical resources with us as we set up our modelling activities. Specific arrangements for our role in this meeting will be forthcoming.

Report on meeting of Primary Productivity Committee — D. Friend

The first meeting was held in San Diego November 13-14th 1971, with Larry Tieszen as chairman. Doug Friend attended as Hawaiian representative. Most time was spent in arranging for better cooperation between biome committees and several recommendations were made to this effect.

1. The services of the Austin office should be used to distribute minutes of each biome committee to the members of other committees.

2. Greater participation by members of other biomes at intra biome meeting probably by attendance of one observer per biome.

3. Increase in personal correspondence about meetings and projects.

The main work of the committee in the future was seen as the synthesis of information at the interbiome level. The general programs of the biomes were reviewed, the common factor being an attempt to develop a mechanistic model of photosynthesis, growth and production. There are from 8 to 20 projects in most biomes related to production. It was recommended that each biome provide the chairman with a copy of the project outlines in these producer areas. In Hawaii we have just made a start on <u>one</u> project in this field.

Further time was spent on attempts to facilitate interbiome comparisons of methods, particularly for gas analysis and harvesting. To aid in this, a Plant Ecophysiological workshop on methods will be set up. Besides specific standards for sampling, it was recommended that soil moisture and nutrient status should also be determined. It is hoped that standard gas cylinders for photosynthetic methods can be circulated between biomes. It was strongly felt that as most primary productivity work has almost been completed in most biomes (Hawaii has not yet started!), mineral nutrients will be the next field of emphasis. It is hoped that shared facilities will be available for mineral analyses.

A second meeting is planned in Arizona in March or April to start the synthesis of material from biome productivity projects.

To summarize, these meetings will be most useful to us in Hawaii, as we can adopt standard methods used in other biomes, and also plan to gather information that is immediately needed for intra-biome comparisons by the modellers.

Report on meeting of Meteorology Committee

P. C. Ekern

The Meteorology Committee of the IBP met in San Diego, California, 10 December. Most pertinent among the topics discussed was the calibration of sensors, particularly radiation sensors, with a common reference required among the biomes if comparisons of this primary meteorological parameter are to be possible. Among other topics, the importance of modeling, and the parameters required of the meteorologist as input for the many models under way seemed to loom as an area of major importance in the design of meterological programs. A field trip on 11 December to the inland site of the Mediterranean biome laid immediate stress on instrumental sensor, recorder, and interpretation demands.

Membership on IBP Environmental Progr . Specialist Committees

	Infor. Storage & Retrieval	Modeling	Phenology	Nutrient Cycling	Meteorology	Decom-position	Consumer Processes	Primary Productivity
Coniferous Forest	Bruce Bare	Bill Hatheway	Art McKee	Dale Cole*	Lloyd Gay	Frieda Taub	Wm. P. Nagel	Dick Walker
Grasslands	David Swift	George Innis	Norm French*	Jim Gibson	Bob Burman	Frank Clark	Dick Rice	Jack Marshall
Deciduous	Nancy Sollins*	Bob O'Neill	Helmut Lieth	Gray Henderson	Kenneth Knoerr	Martin Whitkamp	D. A. Crossley	W. F. Harris
Desert	Charles Romesburg	Kent Bridges	James MacMahon	John Skujins	Inge Dirmhirm	Eugene Staffeldt*	Robert Chew*	Duncan Patten
Tundra	Robert Porter	Phil Miller*	Patrick Webber	Keith Van Cleve	Gunter Weller	Robert Benoit	Steve MacLean	Larry Tieszen*
Upwelling Eco	Perkins Bass	John Walsh		Dick Dugdale				
Tropical Forest								
Mediterranean & Desert Scrub	Beryl Vuilleumier	Norm Slade	David Parsons	Charles Love	William Smith		Andrew Moldenke	Mike Barbour
Island Eco	Sandra Yamashiro	M. P. Mi	C. H. Lamoureux		P. C. Ekern*	Gladys E. Baker	Mercedes Delfinado	J. C. Friend
Special Member			Forest Stearns					

* Chairman

C-11 - Insect Interference in the Reproduction Cycle of Community Structure Forming Plants, Particularly Seed Feeders

DESIRED STARTING DATE: September 1, 1972
PERIOD FOR WHICH SUPPORT IS REQUESTED: 5 years
PRINCIPAL INVESTIGATOR: W. C. Mitchell

OBJECTIVES:

To investigate the insects associated with seed development of two of the dominant species of trees in the Hawaiian Ecosystem, Acacia koa and Metrosideros sp. Determine the importance of the various insects and their relationship to the host plant. Determine the relationship of the pest insect species to other plants in the same ecosystem and the relationship of these plants to the development of insect populations. Determine the relationships of insects to the sequence of events that occur in the pollination, maturation and germination of koa and ohia lehua seed. This project will be a portion of the Sub-Group entitled "Reproduction Cycle of Ecosystem Structure Forming Plant Interferences, Pollination and Seed Feeders."

PROCEDURES:

1. Make frequent and regular field observations on the insects associated with the buds, flowers, developing seed, mature seed, and germinating seed of koa and ohia.

2. Rear insects in the field to ascertain the biology of the pest species, type of injury, stage of host plant development that is attractive to the insects, period of egg deposition, etc.

3. Examine other plants in the ecosystem to determine if other natural plant hosts occur that will carry the injurious insect populations through periods when koa or ohia flowers or seed are not present.

4. Cage blossoms of the host plants to exclude insects and birds to determine if insects are essential for pollination and seed production.

5. Make observations on parasites and predators of the injurious insects and attempt to evaluate their effectiveness.

6. Utilize Malaise traps, sticky boards, black light traps, etc., to secure information on injurious insect movement and abundance.

7. Compare data on injurious and beneficial insects for koa and ohia to determine the relationships between insects and the host plans. The complex of insect species may vary widely between species of host plant and locality. Such information will help determine the spatial distribution of the insects and host plant species.

B-4

Photosynthesis, Transpiration, and Energy Exchange of Juvenile and Adult Koa Leaves: an extension proposal to the autecology of important native trees.

L. L. Tieszen

Acacia koa is one of the most economically valuable species in the forests of Hawaii. However, at the present time its regeneration and spread is substantially restricted due to direct physical damage of the seedlings and/or sprouts by pigs, goats, and cattle, and due to canopy and soil moisture competition with natural and introduced grasses. The trees possess leaves (=phyllodes) which are strongly inclined and minimize direct light interception and possibly maximize water conservation. In contrast, the juvenile leaves are generally horizontal; however, they do appear to wilt readily. Thus, they seem to maximize light interception when water is not limiting but retain the ability to conserve moisture when it is in short supply. An analysis of energy exchange, water utilization, and CO_2 uptake should lead to an understanding of the adaptive strategy of this species and should provide information relevant to its management.

The overall objective of this project is to characterize the canopy structures and environments of seedlings and trees and to obtain the necessary information on photosynthesis, transpiration, and energy exchange to predict energy, water, and CO_2 budgets under a variety of conditions.

1. Describe physical features of leaves in the canopies and determine "typical" radiation, temperature, and watervapor profiles.

2. Measure field photosynthesis and transpiration of juvenile and adult leaves under controlled conditions of temperature, light and humidity.

3. Develop a canopy model to predict leaf responses.

4. If time permits: Thoroughly characterize photosynthetic response of cloned plants under growth chamber conditions.

This research will be done at suitable locations along the Mauna Loa Transect and in the Kilauea Rain Forest.

Leaf area indices and leaf orientations will be measured for select adult and juvenile systems. Air temperatures will be measured along profiles through the canopies with a network of fine wire thermocouples.

Water vapor will be estimated with dew point hygrometers or special lithium chloride sensors. Radiation will be measured with a portable radiometer. The above will be spot measurements only to provide mainly a comparison of adult and juvenile canopies rather than a synoptic micro-environmental study.

Light and temperature responses for photosynthesis and transpiration of attached leaves and branches will be measured with a Siemens gas exchange system and accessory cuvettes. Sufficient detail will be achieved to separate gas exchange into its component resistances.

Tung Liang

Born: 7 June 1932

Marital status: Married; 2 children.

Degrees: BS in Agr. Engr., National Taiwan Univ., 1956; MS in Agr. Engr. and Appl. Mech., Michigan State Univ., 1963; Ph. D. in Agr. Engr. and Systems Analysis, North Carolina State Univ., 1967.

Positions held: Asst. Engineer, Shimen Dan Const. Co. 1957-58; Asst. National Taiwan Univ., 1958-62; Lecturer, National Taiwan Univ., 1963-65; Asst. Prof., Agr. Engr., Calif. St. Polytech., 1967-68; Asst. Prof., Agr. Engr., Univ. of Hawaii, 1968-71; Assoc. Prof., Agr. Engr., Univ. of Hawaii, 1971-present.

Professional societies: Operations Research Society of America; American Society of Agricultural Engineers.

Selected Publications

Systems Approach in Agriculture. T. Liang and H. M. Gitlin. HAWAII FARM SCIENCE 18(3):4-7

Optimize Agricultural Product Size Sorting Operation by Dynamic Programming Method. T. Liang. JOUR. OF AGR. ENGR. RES. 14(2): 139-146.

Random Function Modeling of Macadamia Nut Removal by Multiple Frequency Vibration. T. Liang, D. Lewis, J. K. Wang, G. E. Monroe. ASAE Paper 70-132. Presented at the ASAE Annual summer meeting, Minneapolis, Minnesota, July 8-10, 1970.

Scheduling Bioproduction Harvest. T. Liang, W. Y. Huang, J. K. Wang, Accepted by OPERATIONS Research for publication.

Optimal Design of Furrow Length of Surface Irrigation. I. P. Wu and T. Liang. Journal of the Irrigation and Drainage Div., ASCE 96(IR3):319-332. 1970.

Systems Approach to the Design of Sprinkler Irrigation. T. Liang and I. P. Wu, ASAE TRANS. 13(5):618-621. 1970.

A Systems Approach to Optimizing Papaya Fruit-Package Weight Control. T. Liang. ASAE TRANS. 13(1):133-137. Jan.-Feb. 1970.

Farm Machinery Maintenance - A Renewal Process Model for Predicting Inventory Demand. T. Liang and D. A. Link. ASAE TRANS. 13(3):395-397. May-June 1970.

Farm Machinery Maintenance - Scheduling Preventive Maintenance by Dynamic Programming Markov Chain Method. T. Liang and D. A. Link. ASEA TRANS. 13(3):398-405: May-June 1970.

Design Conduit System by Dynamic Programming. Journal of Hydraulic Division, ASCE 97(HY3):383-393. 1971.

Ruth A. Gay

Born: 13 January 1934, Omaha, Nebraska.

Marital status: Divorced; 1 child.

Degrees: BS, Colorado State University, 1955; MS, Univ. Hawaii, 1967.

Positions held: Assistant Soil Science Research Officer, Australian Capitol Territory Forestry & Timber Bureau, 1955-56; Forestry Librarian, Colorado State University, 1956-58; Teacher in Science and Mathematics, Park High School, Estes Park, Colorado, 1959-66; Instructor in Botany, University of Hawaii, 1967-present.

Field experience: Plant ecology and taxonomy at University of Wyoming Summer Science Camp; oceanography at Puget Sound, University of Washington; ecology at Pingree Park, Colorado State University; plant ecology at Rocky Mountain National Park, Univ. of Colorado; forest soils in Australia; forest ecology on the Island of Hawaii, Univ. of Hawaii.

Research fellowships: NSF summer fellowship 1966, USDA McIntire Stennis Forestry Program 1969-present.

Scientific & honorary societies: Hawaiian Botanical Society (Exec. Bd. 1971, President 1972), Ecological Society of America, British Ecological Society, Association for Tropical Biology, National Wildlife Federation, Wilderness Society, Phi Kappa Phi, Xi Sigma Pi, Delta Kappa Gamma, Beta Beta Beta, Mortar Board.

Selected publications:

Response of two dry grasses to three soil moisture regimes. Ecology in ed. (with D. Mueller-Dombois)

Invasion of natural vegetation in Waiakea Forest Plantations on the Island of Hawaii. In prep.

Justification for Construction of Two Woodland Cabins

Our funded February 1971 proposal included plans to study at least one transect each on the islands of Maui and Kauai. It was indicated in that proposal that we need to construct woodland cabins on those two islands for that purpose. The areas from which we intend to operate, the NE slope of West Maui and Alakai Swamp on Kauai, have no established accomodations. Rainfall is extremely high at those locations and temperatures are low. Towards the latter part of the third year, some of our investigators will be ready to start working in these areas.

For this reason, we are asking for funds to construct two small woodland cabins, one for each island. The material needs to be flown to the sites by helicopter. This adds $1500 to the construction cost.

Proposed IBP Grant Budget, 03 Year, 1972-73

BUDGET SUMMARY

		Requested from NSF	Institution Contribution
I.	University of Hawaii	$459,266	$57,385
II.	B. P. Bishop Museum	$198,468	$15,747
	TOTAL REQUESTED	$657,734	$73,132